WORLD OIL

INDUSTRY TURNING TO PHOTOGEOLOGY

DETERMINING OPTIMUM DRILLING CONDITIONS

NEW FRAC PROCESS SPURS SPRABERRY

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CEMENTING SERVICES

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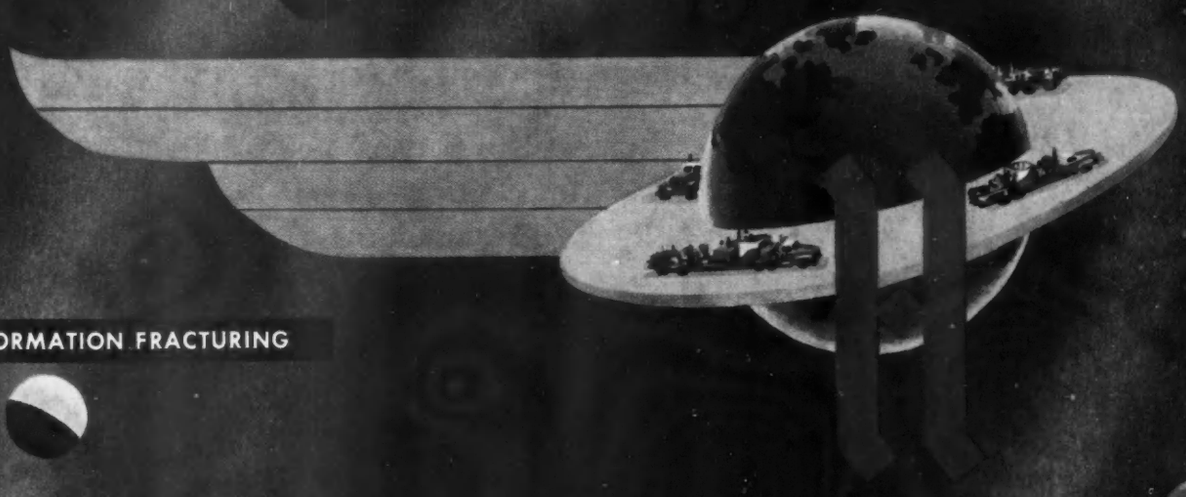

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58—102

Volume 146, No. 4 March, 1958

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WORLD OIL

Established 1916 as The OIL WEEKLY®

a quick look at this issue

BUSY OIL MEN: To help you put first things first, scan these time-saving digests on this and the following pages, checking ☑ those you want to read first.

CURRENT OUTLOOK

☐ **Here is the latest report** on Skelly Oil Company's strike in Harper County, Kansas—one of the most significant for the state during 1957. To date, Skelly has completed 22 wells which produce from the Simpson and Mississippian. Potentials are as high as 3,000 barrels per day. **Skelly Opens "Hot Area" in Kansas** ..... **Page 60**

☐ **If an oil producer ever plans to sell his properties** or to borrow money on them, he will benefit greatly by having made periodic reservoir and evaluation reports on his wells. See **Page 61. What Is Your Lease Worth?** ..... **U. R. Laves**

☐ **Earth satellites** are expected to provide scientific data of benefit to the oil industry. The most direct gain may be the furthering of knowledge of the causes and incidence of sun-spot activity, heretofore obscured and distorted by the earth's atmosphere. Magnetic exploration work may be more reliable when these phenomena are better understood. Short-wave radio transmission and reception may be improved for similar reasons. Turn to **Page 68. How Satellites Can Aid the Industry** ..... **H. T. Brundage**

☐ **Rapid deterioration of U. S. producing health** is illustrated by Texas trends. Texas' production has declined while the number of producing wells has increased sharply. Hence, fewer and fewer production days and less and less output per well is the story in Texas. This is true although U. S. consumption has in-

Turn the Page ▸

QUICK LOOK at this issue . . .

creased 21 percent since 1952. Other sources, notably imports, have benefitted more increased consumption. **Page 75. Texas Producing Conditions Show Rapid Deterioration** ..... **Warren L. Baker**

☐ **The economic health** of the U. S. oil industry deteriorated further during recent weeks. Reduced production and refinery rates failed to correct excessive inventories as demand sagged below expectation. With the low consuming season rapidly approaching, further drastic cuts are scheduled for March. It is becoming increasingly clear that sizable reductions need to be made in import volumes, which continued near record levels. Otherwise, general price reductions seem probable. **Page 76. Oil's Economic Outlook Becomes Critical** ..... **Warren L. Baker**

EXPLORATION ARTICLES

☐ **In 1951 the author** and J. J. Arps collaborated in the design of a calculator called the Arps-Hamilton Loganalyzer, which was made available to the oil industry. Subsequently, they have worked independently and in collaboration to build other slide rules for the calculation of other relationships used in the analysis of electric logs. It was decided in 1956 to merge these units into a new slide rule that would bear all possible useful information. It is this compact slide rule, which provides all corrected basic data and instantly solves equations for the analysis of all electric logs, that is discussed on **Page 81. New Slide Rule Simplifies Electric Log Quantitative Analysis** .... **Dr. R. G. Hamilton**

☐ **The greatest application of photogeology** in the past has been in qualitative geological work. Continuous refinement of this exploratory method was made possible through the use of high-order plotting instruments. Instruments that are most satisfactory for quantitative geologic work have only become available within the past several years. Geological data obtained through quantitative photogeology are used to prepare structural contour maps, profiles, isopach maps, and in hydrodynamic studies. See **Page 85. Quantitative Photogeology a Popular Exploration Tool** ..... **Laurence Brundall and Vernon Jackson**

DRILLING ARTICLES

☐ **To aid in proper selection of the three parameters** for maximum drilling penetration—weight on bit, rotary speed and hydraulic horsepower—under specified conditions, the relationship of these parameters is presented graphically on **Page 93. Graphic Method of Determining Optimum Drilling Techniques** ..... **John W. Speer**

☐ **Clean out your accident closet** by finding the causes of accidents. Examples of accidents, their causes and how mishaps can be prevented during drilling operations, along with the five basic rules of safety, appear on **Page 99. Rig Accidents—Causes and Remedies.**

☐ **A "soft" drive with fine speed** and torque control to the rotary table and drawwork accessories can be provided by a 24-inch coupling mounted behind the drawworks and rigged so the main clutch can be bypassed instantaneously from the driller's console. See **Page 102** for a complete description of this new coupling. **"Run-Around" Provides "Soft" Drive for Rotary Table** ..... **By John N. Schuelke**

☐ **A new down-hole pressure differential tool** can locate lost circulation zones quickly and accurately. This detector, which will send an electrical impulse to the surface, can be run on wireline from standard field servicing units. The mechanics of this tool are explained: **Instrument Pinpoints Lost Circulation** ..... **Page 104**

☐ **Test this new logging device** which is aiding operators in Oklahoma to more accurately determine the true formation resistivities. It has only limited service. For an explanation of this logging method and examples of how it minimizes the effects of the mud column and the effects of the invaded zone, turn to **Page 108. Induction-Electrical Logging in Oklahoma** ..... **H. W. True**

☐ **Advance planning in rig skidding pays dividends.** Thorough study of the terrain over which the rig is to be moved, proper preparation of the rig and selection of best moving equipment are a few of the factors discussed on **Page 118. Advance Planning Pays Off When Skidding a Rig** ..... **Bill Jackson**

PRODUCTION ARTICLES

☐ **Tortuosity and formation factors** are at the basis of multiphase relative permeability studies. For a discussion of existing theories, read the first of a two-part series starting on **Page 121. The Generalized Kozeny-Carman Equation: Its Application to Problems of Multiphase Flow in Porous Media (Part I)** ..... **M. R. J. Wyllie and G. H. F. Gardner**

☐ **Permeability measurements of cores** before and after perforating under controlled conditions are helping engineers determine the effectiveness of various sizes and shapes of jet charges and bullets. For details on this laboratory and what it will mean in increased perforating efficiency, see **Page 128. Tests Revealing New Data on Perforations**... **Gilbert M. Wilson**

☐ **Solvent extraction and miscible fluid displacement** show great promise for increasing recoverable oil reserves. Basic laboratory and theoretical work on solvent extraction processes have shown considerable advancement. This field of engineering is not firmly established but is in the process of evolution. Considerable costly field testing will be necessary to determine field circumstances where solvent extraction processes work most advantageously. See **Page 130. New Methods Show Promise of Increasing Oil Recovery**... **Charles D. Russell**

☐ **Net savings of $552,155 on 71 jobs** in overwater fields of the Louisiana delta have been effected by Gulf through the use of ¾-inch tubing as a workover tool, based on conventional rig costs. The tool can reduce workover costs and broaden the scope of permanent-type well completions. See **Page 135. Workover Costs Reduced With Concentric Tubing Tool** ..... **R. J. Goeken**

☐ **One drilling contractor** has developed a process by which production can be obtained from zones previously bypassed and believed to be unproductive. How? By mixing hydrochloric acid, sand and oil for a combination acidizing and fracturing treatment which resulted in the completion of wells in the Spraberry-Clearfork for economical production. Details are on **Page 148. Combination Treatment Spurs Spraberry-Clearfork Production**..... **T. D. Pugh, Jr.**

☐ **For an equation** by which the water influx can be determined if the cross-section of the reservoir, change in the oil-water contact and certain other reservoir data are known, see **Page 157. Determining Water Influx from Production Data**..... **F. W. Cole**

INTERNATIONAL

☐ **The Persian Gulf's second offshore oil field has been found** by Arabian American Oil Company at Manifa, as exploration makes rapid strides in Saudi Arabia. See **Page 159. Manifa Is Second Persian Gulf Offshore Discovery.**

Looking ahead at exploration

WHAT DOES the future hold for exploration activity?

WORLD OIL's special Exploration Progress Issue, to be published April 1, will provide many answers by outstanding authors and authorities in the exploration field.

Included in this packaged presentation of exploration developments will be technical discussions of:

- Complex geophysical problems in Algeria's Sahara desert, a new frontier for seismic prospecting.
- Geological and geophysical problems and their effect on future exploration activity.
- Refinement of techniques, methods and equipment to cope with increasing geological and geophysical problems.
- The outlook for the Paradox Basin—a U. S. "hot spot."
- Aerial color photography, which is rapidly becoming an increasingly important new exploration tool.

This special exploration coverage, of course, will be in addition to technical drilling and producing operating articles and money-saving hints as well as the current outlook for the oil industry on other subjects of immediate interest.

PREVIEW OF SPECIAL REPORTS

Deluxe World Oil Issues on Schedule

Subscribers of WORLD OIL can look forward to a tasty reading diet during the remaining months of 1958. Every issue of WORLD OIL is carefully planned to be of value to oil men, and here are previews of several future ones you'll like:

Exploration Progress will be the theme of the April issue. It will carry latest information on new developments and trends in the fields of geology and geophysics . . . up to date data on how and where oil is being found.

Gulf Coast Issue in June will feature one of the great oil producing regions of the world. Published every two years, this issue is always popular. One of its highlights will be a 24-page section in which several well-known industry men will give an evaluation of the Gulf Coast past history and future possibilities.

International Outlook, coming up on August 15, will carry basic information on oil producing nations all over the world. In addition, there will be the annual Mid-Year Review and Forecast, of interest to everyone.

Drilling Progress Issue, scheduled for October, will deal with problems and progress in drilling techniques throughout the industry. The job-help material found in this issue can be retained and referred to for months.

In WORLD OIL, *subscribers receive a business publication that is second to none in its field. Every issue has something of value for you in it. It's a work book that can be used right on the job.*

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WORLD OIL and THE COMPOSITE CATALOG for the drilling-producing industry.

PETROLEUM REFINER and THE REFINERY CATALOG for the refining-natural gasoline-petrochemical industry.

PIPE LINE INDUSTRY and THE PIPE LINE COMPOSITE CATALOG for the oil and gas pipe line industry.

Indexed by Industrial Arts Index and Engineering Index

Looking Ahead . . .

Make or Break in '58 . . . Many small oil operations are expected to drop by the wayside before industry's oversupply problem is ironed out. Reasons:

Despite biggest production cutback in many years, crude stocks are still more than 20 million barrels higher than year ago levels, and another substantial cut is on the way. Refinery crude runs are being sliced to the bone. If top heavy inventories aren't cut sharply, bottom may fall out of crude and refined product prices.

Imports are becoming biggest villain in eyes of a growing number of oilmen, because of continued high import levels in face of sagging demand and big cut in U. S. production. Consequently, stronger pressures are being exerted to replace voluntary import program with mandatory federal controls.

During four weeks ended February 14, crude imports were 131,000 barrels per day greater than same '57 period, although 250,000 barrels below peak of last August (See *Observatory*, Page 76). Oil's economic problems will remain critical until crude imports are reduced at least 200,000-250,000 barrels per day to 750,000-800,000 barrels per day average. Sharp cuts in refined product imports are also definitely in order.

But, Will They Find Oil? . . . Seven of the nation's top drilling experts say U. S. can match Russia's boast of having rig capable of drilling a 50,000-foot hole. Spokesmen are confident that all drilling problems could be solved. Biggest hurdle: High temperatures at extreme depths. Informed estimates range up to 1000° F. However, some doubt is expressed as to whether oil or gas would be found at such depths.

New Platform for Record Offshore Water Depths . . . Tulsa firm announces it has offshore drilling platform that will operate in water six times deeper than that worked by present rigs. Platform can be converted economically from mobile-type to permanent rig, and can operate in 600-foot water depths. Rig has own diesel power system to raise itself on tripod legs.

Nasser's Vice Tightens on Mid-East Oil . . . Egypt-Syria confederation puts Nasser in control of Tapline, IPC pipe lines and Suez Canal, the primary transit lanes for Mid-East crude moving to Western Europe. Squeeze on oil may have been one of Nasser's motives in combining two nations whose economies are so similar there is little reason for merger strictly for economic reasons.

Lubricating Muds Cut Drilling Costs . . . Gulf Oil researchers have reported a major breakthrough against steadily increasing drilling costs. The money saver: Conventional drilling mud with small amount of a newly developed extreme pressure lubricating oil mixed in.

Extensive field tests indicate that by doing a better job of lubricating drill bit bearings and drill hole, the inexpensive additive may:

- Increase life of drill bits two to five times.
- Cut time to drill deep wells by 12½ to 25 percent.
- Reduce number of 'round trips," thus cutting down on pipe and rig wear.

Gulf will share new development with industry through licensing to mud service organizations.

Good Wells Make Good News

A Monthly Report Of Successful Well Treatments

March 1, 1958

For sustained production increases from many formations, fracturing is often recommended over any other stimulating technique. "Frac" sand provides a permanent propping action in formation fractures — to improve the drainage characteristics of the well. Here are some recent examples of what has been achieved with Dowell fracturing services.

- **Reagan County, West Texas.** (Old well) Production from this Spraberry well had declined to 15 bopd. Dowell recommended fracturing with Petrojel* to increase production. Treatment was performed using 60,000 gallons jelled crude and 90,000 pounds sand. Because the well was producing from three sets of perforations — 6583 to 6607, 7436 to 7460 and 7486 to 7492 — 275 ball sealers were used during treatment. Injection rate averaged 53 bpm at 1600 psi. *Well tested 100 bopd 33 days after treatment.*

- **Beaver County, Oklahoma.** (New gas well) This well was completed through perforations in the Hoover formation (4450 to 4484 feet). Duofrac* was recommended as the best fracturing service to bring in this well. Dowell fractured using 30,000 gallons three per cent acid carrying 1 pound sand per gallon. In this case a surface tension reducing agent and FLA* (Fluid Loss Additive) were also used. Injection rate averaged 55 bpm down casing. *Production increased from a show to 40 mmcfd.*

- **Hamilton County, Illinois.** (New well) Petrojel was used to fracture this well drilled in the Aux Vases. Casing was set and perforated from 3118 to 3148 feet, four shots per foot. Dowell fractured with 15,000 gallons jelled crude and 15,000 pounds sand at an average injection rate of 31 bpm. 35 ball sealers were injected midway through the treatment. *Well flowed 2030 barrels of oil during the first 20 hours it was opened, and levelled off at 1437 bopd after it cleaned up.*

- **San Juan County, New Mexico.** (New well) Completed in Mancos sand through perforations, 1130 to 1182 feet and 1222 to 1285 feet, this well tested 20 boph. Because of thick pay section, operator wanted to fracture and retest. Dowell recommended Sandfrac*, using 65,000 gallons lease crude and 65,000 pounds sand. Injection down 5½-inch casing averaged 76 bpm. 150 ball sealers were injected behind first 30,000 gallons fluid to divert remaining fluid into less permeable zones. After treatment, *well flowed 120 boph on a prolonged test.*

Dowell offers nine basic fracturing services and an infinite variety of modifications to meet the specific requirements of any well. For more information or service, call any of the 165 Dowell offices in the United States and Canada; in Venezuela, contact United Oilwell Service, or write Dowell Incorporated, Tulsa 1, Oklahoma.

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Stop playing political football with natural gas

THOUGH DISASTROUS for the natural gas industry, the timing was perfect.

On January 7, House Speaker Sam Rayburn and House Interstate Commerce Committee Chairman Orin D. Harris almost simultaneously expressed cautious optimism that the Harris-O'Hara natural gas bill would be passed by the House of Representatives early in February.

From mid-January through early February the roof fell in on the Harris-O'Hara bill. In rapid succession anti-free enterprisers fired the following salvos:

- A study of consumer gas rates by Peter J. McCormick of the Milwaukee Public Library was sent to Wisconsin Senator Wiley. No one has yet figured out what makes McCormick an expert on the natural gas industry. Nevertheless, using the librarian's material, Senator Wiley urged the Senate to kill the "dangerous" natural gas bill. "If this bill is enacted," he said, "30 million natural gas consumers can expect increasing rates" totaling $500 million annually.
- Coal interests stepped up their efforts to tack on amendments that would make the bill completely unacceptable to the natural gas industry.
- A national newspaper chain headlined the rumor that the firing of Bernard Schwartz as chief counsel of the House Commerce Committee was closely connected with a political "deal" involving the natural gas bill. The "deal," supposedly, was this: House Republicans had promised to deliver enough GOP votes to insure passage of the gas bill only if the Democrats would agree to soft pedal any probe of the regulatory agencies which might embarrass the Eisenhower Administration.
- On the same day the Schwartz rumor was publicized across the nation (February 11), a Washington, D. C. newspaper, under banner headlines, completely distorted the meaning of a letter written by Republican National Committeeman H. J. Porter of Houston. One statement in the letter, repeating the well known fact that Joseph W. Martin had supported the natural gas bill in the past, was ballooned completely out of proportion to its meaning. This statement was included in only about 20 out of several hundred letters. Again anti-free enterprisers leaped at a straw and threw it in the face of the natural gas industry. They insinuated "oil-rich Texans" were trying to buy passage of the gas bill. Some critics were quick to let every interested person know that Porter's "ill-conceived" statements had signed the death warrant for the natural gas bill, at least for this session of Congress.

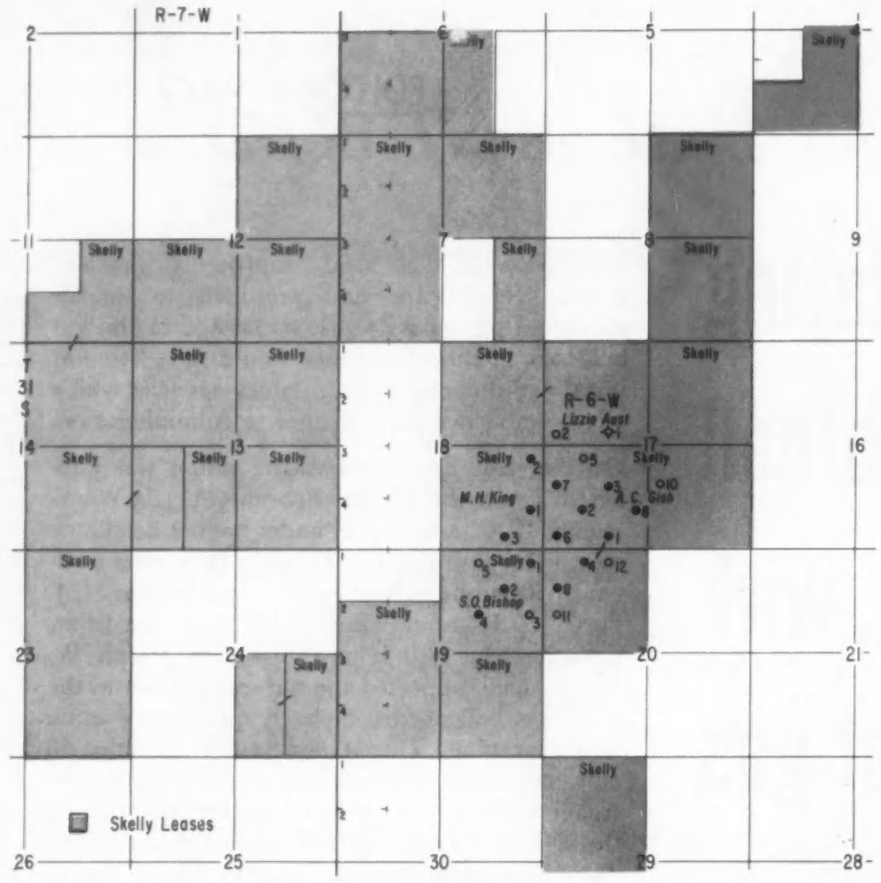
The sad fact is they may have been right about the bill being killed. But why? Why would responsible representatives of the press and government combine poorly represented information with distortions of the truth to condemn the Harris-O'Hara bill?

Giving at least some of the natural gas critics full benefit of the doubt, it could be that somewhere along the line they have been completely misinformed as to the long range harm federal regulation can inflict on natural gas consumers. After all, the newspapers and legislators say they are carrying the cudgel to protect the consumer.

If this is true, and these groups are not merely trying to create more votes and subscribers, they should be willing to listen to the truth. And the natural gas industry has plenty of eye-opening facts to present to any person who is open-minded enough to listen.

In short, it is time to quit playing political football with the natural gas industry, and objectively appraise the natural gas bill from all sides, strictly on its own merits.

The future of free enterprise may lie in the balance.



SKELLY STRIKE IN HARPER COUNTY, KANSAS. Skelly Oil Company's discovery in Harper County, Kansas, highlighted activities in that state in 1957. During the year Skelly completed 22 producers in the Gish field, some with top potentials of 3,000 barrels per day. Pay is from the Simpson sand, with some production from upper Mississippian.

Skelly Opens Promising 'Hot Area' in Kansas

With 20 of 22 wells completed, Harper County strike tops 1957 activities in the state.

ONE OF THE most important wildcat discoveries and field development programs in Kansas during 1957 was made by Skelly Oil Company of Tulsa.

Starting with a discovery on its Gish lease in the northern part of Harper County, Skelly has completed 20 of 22 wells put down on its four leases in this southern Kansas area.

A recent completion on this 100 percent Skelly-owned field, was a well on the Bishop lease which opened a second pay zone.

Discovery well for the pool was A. C. Gish 1, SW SE SW 17-31s--6w, which was completed for 617 barrels of oil a day in the Simpson sand at 4920 feet.

Then the confirmation well, Gish 2, NE SW SW 17-31s-6w, came in for a top Kansas potential of 3000 barrels a day from the Simpson sand at total depth of 4850 feet.

Following the confirmation, 10 other wells were drilled by Skelly on the Gish lease, eight being completed on potentials from 162 to 3000 barrels a day. One was a dry hole. The dry hole will be used as an injection well.

Meanwhile, on Skelly's Lizzie Aust lease to the north, the Aust 1 ended in failure. No. 2 is a producer.

On the M. H. King lease to the west, three more good wells have been completed, and on the S. O. Bishop lease to the southeast, four wells have been completed and one is drilling.

On Skelly's Bishop lease, its Bishop 4, NE SW NE 19-31-6w, gave the field its first Mississippian production and extended the field farther southwest. The Bishop well is rated at 85 barrels of oil a day from pay at 4349-56 feet.

The new pool is located on a low relief anticline, and the dry hole, the Aust 1, apparently defines the northern limits of the field.

The area was initially explored by use of core drilling and seismograph which pin-pointed the structure and led to the drilling of the discovery well.

Pay From 3 Formations. Although principal pay is the Simpson sand, with the Mississippian also producing, good shows have been reported in the Kansas City formation, which is behind pipe and has not been tested.

Allowables in the field for both the Simpson and the Mississippian are 50 barrels of oil a day per well, with the oil being purchased by Skelly and trucked out.

Skelly's production department is keeping two rigs busy developing the field.

Nearest production is the Runneymede field three miles to the east. The Spivey-Grabbs field is six miles to the northwest.

The Gish field is also four miles northeast of the town of Harper. Skelly owns approximately 7400 acres in the immediate area of the new reserve.

Claude Wentworth and others were contractors for the Gish 1. Drilling is described as "pretty easy," and with 20 days average time to drill a well.

—**The End**

What Is Your Lease Worth?

Only a reservoir evaluation can furnish the answer. It is a "must" in selling, borrowing, or buying.

By U. R. Laves
Valuation Geologist, Oklahoma City

THE OPERATOR who makes an effort to obtain as much data as possible regarding his wells at the time of completion and periodically thereafter, is in a much better position to evaluate his leases than is the operator who ignores technical data.

Early evaluation of a reservoir and planning of the most efficient method of operation is indeed a challenge to the engineer and geologist.

Methods of Estimating Oil Reserves. Estimating oil and gas reserves and periodically checking and revising estimates is an accepted practice in the oil and gas business. It is comparable to the periodic accounting of other assets in any well managed organization.

There are several methods of estimating oil reserves, including one which indicates the probable rate of future production. Estimates are made (1) by volumetric determinations in which the pore-volume is calculated and a factor of recovery is assumed, (2) by extrapolation of various curves, (3) by comparison with an older supposedly similar pool or property and (4) by the "material-balance" method. Volumetric calculations and the rate vs. time decline curve are the two methods in general use.

The volumetric method is probably as old as the oil business. However, its accuracy has undoubtedly improved with the development of better techniques for determining reservoir characteristics. The standard volumetric formula, while generally accepted, leaves much to be desired, and the appraiser must use judgment in applying it to a given pool or property. A formula can at best be only as good as the data used and the assumptions made. If the data are correct, the estimate of reserves in place will be fairly accurate. However, the estimated recovery factor may be wrong, because recovery is dependent upon many conditions beyond the control of the appraiser. For example, the degree of reservoir energy conservation practiced by the operators and the price of oil may have a direct bearing on the amount that will be recovered.

Other assumptions involved in the volumetric methods are the uniformity of thickness, permeability, porosity and oil saturation of the pay horizon under the property being evaluated. The appraiser needs to consider whether it is probable that the reservoir characteristics obtained from a bore hole with a diameter of a few inches is representative of a tract with an area of 10, 20, 40, 640 or more acres. The need for judgment when evaluating a property on the basis of the limited information generally available from a new discovery well is quite obvious. The wisdom of periodic revisions as development progresses is clear.

The concept of volumetric calculations is quite simple if one visualizes a rectangular tank whose base has the area of one acre and whose sides are one foot in height. Such a tank would hold 7758 barrels (42 gallons per barrel) of fluid, or to express it differently an acre-foot of space has a capacity of 7758 barrels. Since an oil reservoir consists of rock and pore-space filled with fluids and/or gas, a formula is needed for calculating the capacity of the pore-space in the reservoir in order to estimate the oil and/or gas reserves trapped therein. An acre-foot of reservoir will therefore contain 7758 barrels of fluid less the space occupied by the material comprising the reservoir rock. All of the pore-space, however, is not available for the accumulation of oil or gas, because of connate water, and the formula must allow for this.

The following equation meets these requirements for estimating the oil in a reservoir:

(1) 7758 x P x O equals barrels of reservoir oil per acre-foot.
where 7758 = bbl. per acre-foot
P = porosity in percent or reservoir volume
O = space for oil (after deducting space occupied by connate water) expressed as percent of pore-space.

Oil under pressure in the reservoir

contains dissolved gas, and when it reaches the stock tanks at the surface under atmospheric pressure, it has lost gas and shrunk in volume. The amount of shrinkage depends upon the amount of gas dissolved in the oil and can be determined. When the shrinkage factor or formation volume factor has been determined the reservoir oil may be calculated in terms of stock tank oil in place by dividing the barrels in equation (1) by the formation volume factor. This amount is then multiplied by the estimated recovery factor.

An example will illustrate use of the volumetric formula with the following assumed reservoir characteristics and estimated recovery factor:

Porosity	18 percent
Connate water	30 percent
Formation volume factor	1.2 percent
Recovery factor	20 percent

(2)

$$\frac{7758 \times .18 \times .70}{1.2} = 814 \text{ bbl./ac. -ft. stock tank oil in place.}$$

(3)

814 x 20 percent = 163 bbl./ac.-ft.

recoverable stock tank oil in place. After determining the estimated recoverable oil per acre-foot this amount is multiplied by the thickness of the net pay horizon in feet and the estimated drainage area in acres.

Since volumetric calculations are not based on precise data, a slide-rule or nomograph is useful in speeding calculations.

The decline curve, in which the rate of production (per day, month or year) is plotted against time, is probably the most used method of estimating reserves where unrestricted production history is available. A great advantage of this curve lies in the fact that it also indicates an estimate of the rate of decline in future months, a feature particularly useful for predicting future income. When plotted to show the average daily rate of production during each month, the curve may call attention to mechanical trouble by indicating increase in rate of decline. It may also indicate dissipation of reservoir energy when a high gas-oil ratio well in a structurally higher position is put on production.

Although the rate vs. time decline curve requires capacity production it is probably the most reliable tool for estimating reserves, especially when it is based on a long history of production. Semi-log paper is generally used for rate-time extrapolation.

Two other useful curves are the rate vs. cumulative oil curve and the bottom-hole pressure vs. cumulative oil curve. The former requires capacity production and works best for a gas solution reservoir. This curve is plotted on semi-log paper. The latter curve may be used in a gas solution reservoir not affected by a water-drive. Coordinate paper is generally used for this curve.

Comparing With Older Pools. The comparative method for estimating reserves employs the production history of an older pool or property as a means for estimating reserves in a new pool or property producing from the same horizon. Generally, recoveries in the older area are reduced to barrels per acre or to barrels per acre-foot and then are applied to the new area. This method is widely used by individuals not concerned with more accurate estimates or who may not have access to reservoir data in the new area. The comparative method lends itself to optimistic predictions, based very often on unfounded assumptions. The fallacy of the method lies in the fact that there probably are no comparable pools or properties. The method may have been justifiable before core analyses and electrical log interpretations came into such general use and pointed out the differences existing in "comparable" fields.

The "material balance" method of estimating reserves is perhaps the most accurate method now available. However, it is applicable to an entire reservoir and not to individual leases. This method requires much more information about a reservoir's characteristics; the amount of oil, gas and water produced; its temperature and pressure than is generally available.

Secondary Reserves. The methods described above have dealt with primary reserve producible by the natural energy found in the reservoir. It has been shown that considerable oil is left in the ground after this energy has been exhausted. Much of this oil can be produced by injecting artificial energy into the reservoir during the secondary recovery phase of exploitation.

Estimating secondary reserves involves estimating the oil originally in place and then deducting the oil produced by primary methods. The percentage of oil recoverable by primary production varies with the source of reservoir energy and may range between 10 to 35 percent in solution-gas reservoirs and 40 to 70 percent in water-drive reservoirs. Before beginning secondary operations, it is customary and advisable to verify secondary reserve estimates by drilling core holes and analyzing the cores. It is not advisable to rely entirely on the "increase due to water-drive" shown on core analyses made early during primary development, because the "increase" refers to a complete natural water-drive, seldom realized in secondary flooding operations. These artificial floods may recover only 50 percent of the "increase" indicated.

Estimating Gas Reserves. Some of the methods used in estimating natural gas reserves are similar to those employed for oil reserves. Broadly speaking there are two types of gas occurrence in a reservoir:

(1) Dry gas not associated with oil production.

(2) A gas cap and gas dissolved in oil.

Dry gas reserves may be estimated by volumetric calculations which take into consideration the reservoir pressure, and also by observing the volume of gas produced per pound of pressure drop. The latter method is particularly useful when the extent and thickness of the reservoir cannot be ascertained.

Estimates of gas associated with oil are generally less accurate than estimates of dry gas, because of changes in operating conditions and rates of withdrawal. Gas-oil ratios are sometimes assumed to be constant, and gas reserves are then related to estimated oil reserves. The value of the gas and its liquid products produced per barrel of oil are sometimes combined with the value of a barrel of oil into a unit price. The unit price is then multiplied by the estimated oil reserves.

Valuation Reports. After estimating reserves by one or more of the methods previously mentioned, their value may be determined and reported in a formal Valuation Report.

Valuation reports are prepared for many purposes, and may be required frequently during development of large leases or at stated intervals in connection with periodic financial re-

ports. They are used by management in planning development; by seller and purchaser in negotiating a sale; by companies in connection with mergers or consolidations; by borrowers and lending institutions when financing is being arranged; by accountants as a basis for depletion and depreciation accounting (some operators overlook the tax advantage of cost depletion over statutory percentage depletion because they do not maintain a record of their reserves in the ground); by companies issuing stock; by individuals and trust departments concerned with estate matters and for many other purposes.

A valuation report is not a precise report, since it is based on estimates of reserves and assumptions regarding future demand and price of oil. Its preparation requires both experience and judgment in weighing the many problems involved. Some appraisers try to allow for errors by using a discount (hazard) factor. However, this is not considered good practice by those who prefer to express their judgment and call attention to the assumptions that have been made.

In some so-called "seller's reports," reserve estimates are inflated to support the purpose for which they are written, thereby becoming sales literature under the guise of technical wording. Conversely, "buyer's reports" may be slanted conservatively. The reasons against such practices are obvious and underscore the need for a "single standard of morality." Facts should be the basis for every report. Neither a conservative nor optimistic viewpoint is desirable. In this way, management, seller and buyer, lending institution and borrower, are fully informed and in a position to judge and negotiate.

When preparing a valuation report for a particular purpose, it is important that the writer is familiar with the specialized information required and that he direct the report to that purpose.

For example, a valuation report prepared in connection with a bank loan may not be as complete in some respects as one prepared for other purposes, because the lending institution is concerned primarily with current and future production of the wells producing at the time the loan is made. A lender is less concerned with horizons not currently producing on the property to be mortgaged, because they do not represent dependable loan value. If they are mentioned in the report, any value indicated for them should be segregated. Also, the bank report may go into greater detail regarding financial matters than is customary on reports for other purposes, because the bank is concerned with dollar income and the ratio of the loan to the value of the estimated reserves. Discussion of specialized reports will illustrate the need for including information required in particular situations.

Bank Loans. After estimating the reserves, there are several methods for determining their value. One concept is "fair market value." It is a strictly legal term, defined as the price at which a willing and able buyer and a willing seller, not forced to sell, would trade if both were reasonably well informed of the facts. Some banks arrive at what they consider fair market value by discounting estimated future net income at a rate which will indicate that value.

Discounting estimated future net income at the prevailing interest rate, and dividing the results by two, is a method frequently used to arrive at loan value.

A rule-of-thumb postulating a per barrel value for oil and a MCF value for gas in the ground is another method.

All of these methods, and others not mentioned, are for the purpose of making certain that the value of the property is sufficient to repay the loan, if it becomes necessary to sell it.

Some banks prefer that the appraiser prepare a tabulation indicating the total estimated future production, the total future net income, and the current monthly income for each lease in the report. Others require a payout schedule which indicates the ability of the properties to generate sufficient net income after taxes to amortize the loan within a certain time.

Generally speaking, banks lend from 25 to 33 percent of the estimated net income (not discounted) of the producing property, or as much as 50 percent of the present worth of future net earnings (discounted at the going rate of interest). The latter method results in a slightly higher loan-to-value ratio.

Repayment of production loans is geared to the estimated income from runs. This is usually done by requiring a minimum fixed payment or a payment of at least 75 percent of the monthly oil runs, whichever is greater. In this fashion, repayment during the term of the loan is assured, and the lender is also protected against undue depletion of collateral if runs are increased.

When discussing a proposed loan the operator soon realizes that banks specializing in oil loans are eager for this business, but that production loans like any commercial loans are made only on sound banking principles of value and payout. The operator who brings his banker an up-to-date report by a valuation engineer or valuation geologist acceptable to that bank, will find that much time will be saved in obtaining a loan. A good record of production history properly tabulated down to date creates a favorable atmosphere for discussing a loan, especially when the prospective borrower knows exactly how much money he requires and how he intends to use it. The old saw, "how much can I git," is not a desirable approach.

An oil operator's business is seldom static, and later he may find it necessary to have his report revised, if conditions require revamping of his loan to take care of additional drilling or for the purpose of selling all or a portion of his interests.

Lease Inspections. Some banks do not require lease inspections and production tests. However, they are often very important and serve to bring all data down to date. Lease inspections and production tests give the appraiser an insight into operations and lease "housekeeping." He is in a better position to form an opinion about the "romance" which sometimes creeps into conversations regarding the capability of wells and leases. After a field trip he may have occasion to ask for gas-oil ratio tests, bottom-hole pressure tests, and other data.

While the foregoing remarks also apply to loans on gas production, it should be noted that in making loans on gas reserves, the lending institution will require assurance of a dependable market for gas sales. A gas contract extending beyond the term of a proposed loan, and providing for a minimum guaranteed take, is essential.

In summary, it is well to emphasize that evaluation of oil and gas reservoirs and individual leases has many purposes, a few of which have been briefly mentioned. Because of inaccuracies in data, difficulty of predicting future production methods, varying demand for oil and gas, and other economic influences, all valuations must be considered as estimates, based on currently available information. Accepted procedures and methods of evaluating have been in use for many years, and have been relied upon by management, lending institutions, and individuals. It can be assumed, as techniques are improved and new ones are developed, that reservoir evaluation and valuation reports will become increasingly important to the oil and gas industry and investors.

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About the Author

U. R. (BILL) LAVES received his M.S. in geology from the University of Chicago in 1925 and then went to Oklahoma as surface geologist for Shell Oil Company (Roxana Oil Company). Prior to that time he did reconnaissance geology in the Dominican Republic, West Indies, and Columbia, South America, and supervised diamond core drilling in the Finger Lakes region of New York. After leaving the Shell Oil Company in 1928, he worked for Tide Water Associated Oil Company and others in the Greater Seminole Area. Laves went to Oklahoma City in 1948, where he is a consulting geologist specializing in valuation work, primarily in connection with bank loans, in Oklahoma, Kansas and Texas.

If Oil Could Speak

If oil could speak it would have many fascinating truths to tell the non-oil public—truths that would win thousands of new friends for the oil industry.

But, oil can't speak—you can. You, as an individual, can win many new friends for the oil industry if you will pass the true facts on to your non-oil industry friends.

Here are some of those true facts. They are being presented for one purpose: To keep you posted on your industry, so you can tell the story oil is unable to relate.

Read these facts. You will find them informative—and interesting.

How Much Gasoline Are We Using?

About 1.4 million gasoline pumps pour almost 48 billion gallons yearly into the fuel tanks of nearly 63 million automobiles, buses and trucks. This flow supplies liquid power for travel over U. S. highways that averages over a million miles every minute of the day.

Does the Oil Industry Pay Its Share of Taxes?

Oil companies pay more than their share. During the postwar years of 1946 through 1952, oil and gas producers paid roughly twice as much in U. S. income taxes on each dollar received as did the average industrial corporation.

How Much Does It Cost to Find Oil?

Oil and gas can only be replaced by finding new supplies; that is, new oil and gas reserves, and the finding of these reserves calls for extensive exploration programs, costing billions of dollars. On the average, a wildcat well costs $100,000, but some cost over $500,000. Only one in nine such wells strikes oil, therefore, on the average the oil man must invest $900,000 before he discovers one producing well. The manufacturer does not build nine factories before he finds one that will produce goods for sale, thus, the manufacturer spends $100,000 and is ready for business, whereas the oil man spends $900,000 before he gets any production.

Are Oil Profits Getting Bigger?

No. Oil profits have not kept pace with costs. The cost of drilling and and production has gone up. Since 1952, oil field machinery and tool prices have risen almost 25 percent; carbon line pipe has risen more than 68 percent; alloy casting is up nearly 56 percent—but crude prices are up only 23.3 percent! Oil prices must be adequate to make the risk of financing oil ventures worthwhile.

Are Major Oil Companies Doing Most of the Business?

Small, independent businesses, with little risk capital, drilled almost 78 percent of the wells completed in 1956. They risk not only their own money, but also the savings of thousands of investors all over the country. Oil men are hard pressed to get funds for investments that won't begin paying off for several years. Most of the output of oil wells being completed now will be used to meet increasing future consumption rather than current demand.

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Stewart-Warner Corp.
Stewarts and Lloyds Ltd.
Joe Stine Inc.
Stone Instrument and Supply Co.
Stratoflex, Inc.
Sunset Engineering and Supply Co.
Sunshine Iron Works
Sweet Oil Well Equipment, Inc.
S. G. Taylor Chain Co., Inc.
Taylor Instrument Companies
Technical Oil Tool Corp.
Templeton, Kenly & Co.
Texas Creosoting Co.
Texas Flange Co.
Texas Gulf Tank Co.
Texas Iron Works, Inc.
Texas Tool & Machine Co., Inc.
Texsteam Corp.
Textron Inc.
Thermal Activators, Inc.
Thermix Corp.
Thermoid Co.
N. V. Motorenfabriek THOMASSEN
Thompson Tool Co.
Thornhill-Craver Co.
Timken Roller Bearing Co.
Toledo Pipe Threading Machine Co.
Tretolite Co.
Tripplehorn Co.
Tri-State Oil Tool Co.
Tuboscope Co.
Tubular Lining Corp.
Tulsa Winch
Turbolite Co.
20th Century Manufacturing
Twin Disc Clutch Co.
U. S. Industries, Inc.
Unibolt Division, Thornhill-Craver Co
Union Carbide and Carbon Corp.
Union Chain and Manufacturing Co.
Union Machine Co.
Union Tank and Supply
Union Wire Rope Corp.
Unit Rig & Equipment Co.
United States Motors Corp.
United States Rubber
United States Steel Corp.
Universal Atlas Cement Co.
Universal Packing & Gasket Co.
Varel Manufacturing Co.
Vickers, Inc., Tulsa
Victaulic Company of America
Visco Products Co., Inc.
Vortox Co.
W-K-M Manufacturing Co., Inc.
Wagner-Morehouse, Inc.
W. L. Walker Co.
Walker-Neer Manufacturing Co.
Waukesha Motor Co.
Weatherford Oil Tool Co.
Weil Controls, Inc.
Weil Equipment Mfg. Corp.
Weil Instrument Developing Co.
Weil Logging Equipment Mfg. Co.
Westinghouse Air Brake Co.
Wheeling Machine Products Co.
Wheland Co.
White Motor Co.
White-Roth Machine Corp.
Wichita Clutch Co., Inc.
Wichtex Machinery Co., Inc.
Wickwire Spencer Steel Division
Wilkinson Products Co.
J. H. Williams & Co.
Willis Oil Tool Co.
Wilson Manufacturing Co.
Web Wilson Oil Tools, Inc.
Wilson Supply Co.
Winter-Weiss Co.
Win-Well Manufacturing Co.
Alfred Wirth & Co.
Wisconsin Motor Corp.
Witte Engine Works
Woodfield Hoist & Associated Industries Ltd.
Woolley Tool Co.
Worthington Corp.
Yale Machine Works
Youngstown Sheet & Tube Co.
Yowell Service Co.

How Satellites Can Benefit the Industry

Improved mapping work and magnetic exploration will result from information provided by U. S. earth satellites.

By Harrison T. Brundage
World Oil Staff

Scientific data yielded by artificial earth satellites are expected to provide the oil industry with a considerable amount of scientific information that can be put to practical use. Some of the benefits will include:

- Improved magnetic exploration
- Better communications
- More accurate mapping information
- Improved weather forecasts

Improved Magnetic Exploration. Magnetic exploration for oil prospects may be improved considerably in accuracy after data from satellites have been thoroughly analyzed.

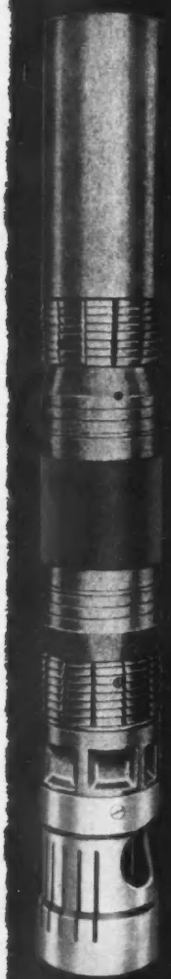
Magnetic storms, associated with erratic and often intense sun spot activity, cause exploratory magnetic data to become at least as thoroughly garbled as occurs in case of some telegrams and cablegrams transmitted during periods of vigorous sun spot activity. This is the best known effect of sun spots. However, the distorting effect applies equally to magnetic readings in reconnaissance oil exploration.

Magnetic storms can be determined by ground monitoring stations, employing conventional magnetometers which are read continuously for severe fluctuations at the same spot. Often associated with sun spot activity, they sometimes occur during otherwise perfect weather.

Generally, magnetic storms tend to be most frequent near the magnetic poles and least so in equatorial areas. They are especially frequent and intense in Alaska where oil exploration, including aerial magnetic work, is ex-

BAKER Packers put the "permanent" in permanent-type completions

When you select a Packer for a Permanent-Type Well Completion, remember this fact: of all the tools used in permanent-type well completions, only the PACKER is required to be *permanent*. Guns, Extensions, Plugs, Gas-Lift and Circulating Valves can be removed or replaced on wire line . . . but the Packer, like the casing, is required to perform for the life of the selected producing intervals. Baker Packer Completions are *permanent completions* from the standpoint of packer performance.



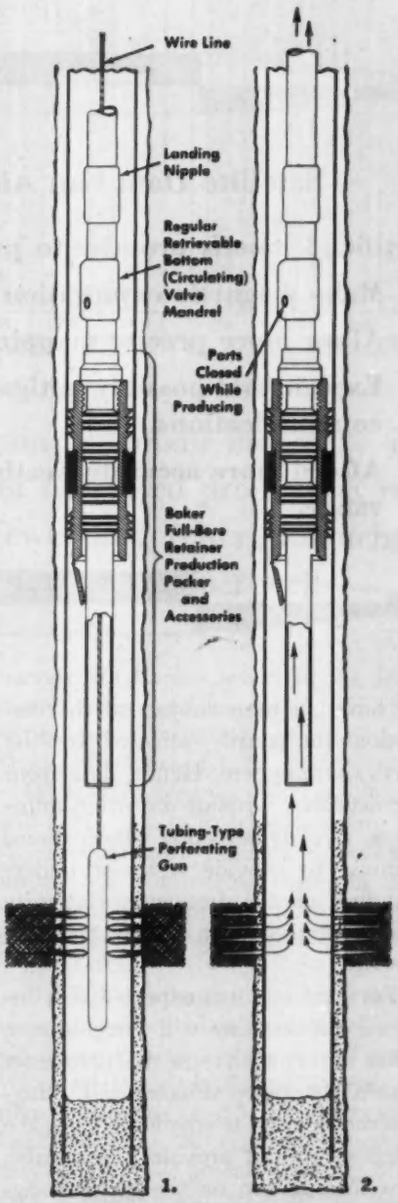
Baker Retainer Production Packer Product No. 415-D

Baker Retainer Production Packers have many important advantages . . . Meet dimensional requirements of Permanent-Type Well Completions; provide permanent, reliable pack-off which will hold against any pressure differential (from above or below) that is safe for the casing; Tubing String is free because neither set-down tubing weight nor tubing tension is required to achieve and maintain pack-off, although the tubing may be anchored to the packer if desired; Tubing String readily removed. Packer can be set on a wire line; is readily drillable, and can be used as either a Squeeze or Production Tool.

BAKER OIL TOOLS, INC.

BAKER

HOUSTON • LOS ANGELES
NEW YORK



One of the many types of Permanent-Type Completions is shown above. After perforating (1) and retrieving the cable head and collar locater, the well is put on production (2). All subsequent work-overs, such as squeeze cementing to improve gas/oil ratios, are conducted with special tools which are run through the tubing string.

pected to reach new heights of activity in the near future.

In rare instances, magnetic storms can affect electrical logs. In such instances, proper operation requires that the log be run again after the magnetic storm has abated, just as a well-advised magnetometer party would suspend operations during a magnetic storm.

Previous studies of sun spot activity have all been subject to the distortions necessarily affected by the earth's atmosphere. Hence, data from the satellites, without distorting influences directly affecting observations, promise to provide a better understanding of the frequency, intensity and general pattern of sun spot behavior.

Furthermore, it is expected that future earth satellites will carry, among other instruments, a magnetometer within the space vehicle itself. Magnetometer data telemetered from the satellites should provide considerable new information on the earth's magnetic field which, of course, will in turn further the science of magnetics and its application to oil exploration.

Better Communications. Since short wave communications are often disrupted by ionized air in the upper atmosphere, earth satellites may lead to improved communications through increased knowledge of the variation of intensity of short wave ultra-violet light emitted by the sun.

Thus, in the future it may be possible to predict when radio "skips" will occur. At such times, a radio car in West Virginia may lose contact with Parkersburg, but will receive signals from Dallas, Texas loud and clear.

More Accurate Mapping. Accuracy of geodetic work is expected to be improved by information from earth satellites. There are considerable variations in the shape of the earth, apart from the well known flattening at the poles and the corresponding bulge at the Equator.

Painstaking triangulation on the continents usually provides maps of sufficient relative accuracy to sustain oil exploration and exploitation. However, the distance between continents and the absolute location of certain islands are said to be off by as much as a mile in some instances, despite rapid strides made in cartographic mapping techniques during recent years.

One aspect of the Inter-American Geodetic Survey program to map all of Latin America from the air is its intimate inter-connection with the Space Satellite program. Precise location of stations to meter signals from the satellites has been established largely by IAGS geodetic work. The accuracy of this work will be checked by data telemetered from satellites, and vice versa, so the two programs are complementary (see WORLD OIL, Geodetic Survey to Spur Latin American Oil Growth, October, 1957, Page 127).

If today's base maps are adequate for oil exploration, tomorrow's can be expected to be even more accurate, thanks to artificial earth satellites.

Improved Weather Forecasts. It is too soon to tell how much we will learn about the weather from the satellites, but expectations are that meteorological knowledge will increase greatly, very likely enough to make possible a certain degree of weather control in the future.

In the first place, the intensity of energy emitted by the sun is not constant, but varies considerably during short intervals, probably in the order of 5 percent variation. Direct monitoring of the sun's energy output will cast considerable light on variations in the earth's weather.

In addition, it will be possible to observe the earth's atmosphere from a new and heretofore unknown vantage point. High-altitude jet streams, at present not fully known nor understood, affect the world's weather to a considerable degree.

Better long-range weather forecasting would enable the oil industry to plan and control fuel oil and gasoline stocks, refinery runs, etc. much more intelligently. Exploration, production, and pipe lining operations in monsoon areas like India and Burma could be planned with more certainty. The same reasoning would apply to muskeg country, such as northwest Canada.

Finally, better understanding of the upper atmosphere which will result from study of the trajectories, orbits and length of life of a number of satellites should lead to the development of better high-altitude aviation fuels and lubricants. This may be of a somewhat negative aspect insofar as oil companies are concerned, since the trend in high altitude fuels and lubricants seems to be definitely away from hydrocarbons, and toward the development of other types of chemicals.

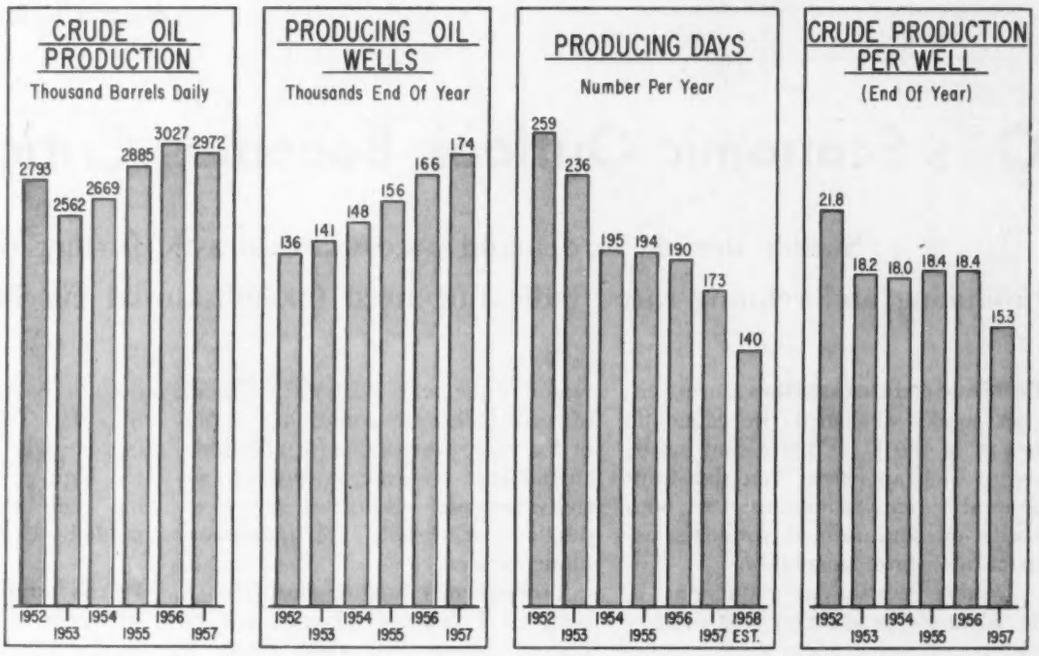
However, some oil companies already deeply involved in the manufacture of a variety of chemicals may wish to join this trend, rather than simply watch it with academic interest. **—The End**

Satellite Data Can Aid Industry Operations

Artificial moons promise to provide data that will:

1. **Make magnetic exploration more accurate.**
2. **Allow more precise mapping.**
3. **Explain and possibly mitigate distortion of short-wave radio communications.**
4. **Afford more accurate weather forecasting, particularly long range.**

TEXAS OIL PRODUCTION TRENDS



Texas Producing Conditions Show Rapid Deterioration

Steady gain in producing wells in the face of decreased production results in fewer and fewer producing days and less output per well.

By Warren L. Baker
Editorial Director
World Oil

The current unhealthy condition of the U. S. oil industry is illustrated by the steady deterioration of producing conditions in Texas. Constant growth in number of wells, in the face of little change in production, has resulted in a smaller and smaller output per well.

Texas producers have not benefited from increased consuming rates during the past five years. Between 1952 and 1957 Texas crude production increased only 7 percent, although rates in late 1956 and early 1957 were boosted substantially by emergency shipments to Western Europe during the Suez Canal crisis. In contrast, total consumption of U. S. oils rose 21 percent between 1952 and 1957.

The picture changes drastically for 1958. Texas crude production is not likely to average more than 2,725,000 barrels per day in 1958, perhaps even less. Thus, Texas may produce at least 68,000 less barrels per day in 1958 than in 1952, despite the gain made in U. S. oil consumption.

The foregoing only partially tells the story of deterioration in Texas producing conditions. Although Texas is expected to produce less oil in 1958 than in 1952, the number of producing oil wells in the state has shown substantial increase. At the end of 1957, there were 174,000 producing oil wells being operated in Texas. Thus, 38,000 more wells than in 1952 are trying to share in the reduced Texas production.

The increase in producing wells, during a period when restricted market outlets have prevented much growth in production, has resulted in a steady decline in the number of allowable producing days in Texas. In 1952, the state had 259 producing days, and the number had been higher in previous years. There were only 173 producing days during 1957.

When wells steadily increase in number and production drops, the inevitable happens—daily crude production per well declines. At the end of 1957, with production down to 2,700,000 barrels per day, average daily production per well was 15.3 barrels, 3.1 barrels less than the 18.4 barrel average at the end of 1955 and 1956, and 6.5 barrels per day less than at the close of 1952.

With conditions as they are, Texas will be fortunate to have as many as 140 producing days during 1958. This means a slight increase later in the year, as there were only 12 producing days in January, 11 in February and 9 in March.

Obviously, other sources have been benefiting more from increased U. S. oil consumption than has Texas. Whereas Texas' 1958 crude production is likely to be 2.5 percent below 1952, total U. S. crude production may be 10 or 12 percent greater. But, even if crude oil imports for the year 1958 do not exceed present government restrictions of 991,000 barrels daily, they will be 73 percent above 1952 rates; and imports of refined products are likely to be 35 percent larger.

Producers in other states, as well as in Texas, need quick relief from such conditions. But there is nothing on the horizon at this time which promises any early alleviation. — **The End**

Warren L. Baker, Editorial Director

Oil's Economic Outlook Becomes Critical

Sizable decline in demand necessitates drastic further reductions in U. S. producing and refining rates, indicating need for substantial cut in imports.

Continued deterioration during recent weeks weakened the economic health of the U. S. petroleum industry to such an extent that disastrous general price reductions for both crude oil and refined products became a distinct possibility.

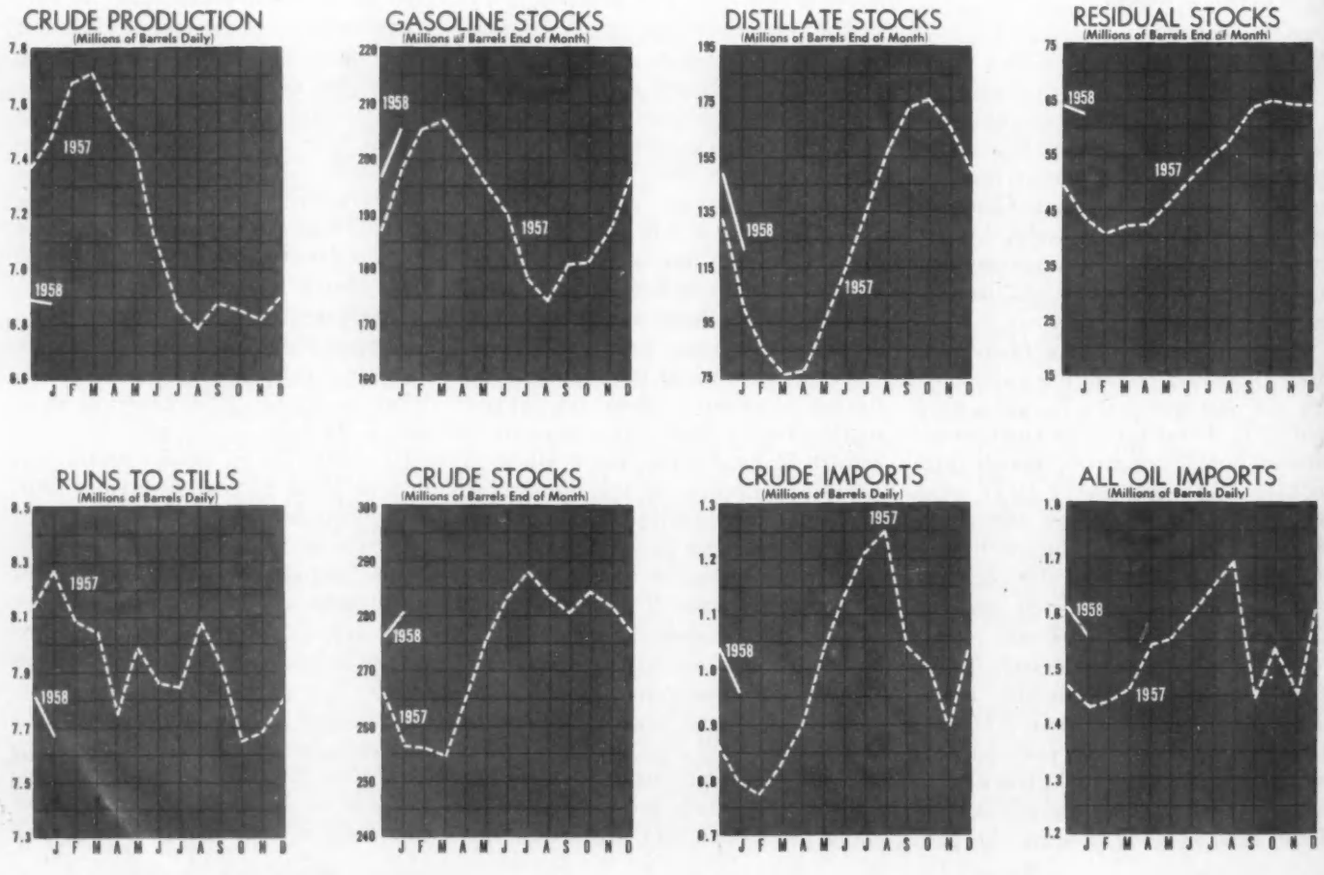
Despite substantial reductions in U. S. crude production and refinery output, excessive stocks were not corrected as demand failed to live up to expectations because of further slowdown in general business activity. This has been particularly disappointing because winter months invariably are the largest oil consuming season of the year. With the approach of spring, lowest consuming period of the year, prospective for additional curtailment of general business activity presages additional severe reductions in supply are mandatory immediately.

Consequently further sharp cuts in both U. S. crude production and refinery output will take place in March. Crude production will be at the lowest level in nearly four years, and almost 1½ million barrels below March, 1957. On the other hand, combined imports of products and crude continue at near record levels, despite government curbs on crude imports. Therefore, it is becoming increasingly clear that imports are too high, and should start contributing their share to the curtailment made by U. S. producers and refiners.

Prices have weakened appreciably in recent weeks, and now are in very serious condition.

Both wholesale and retail prices of refined products tended downward in recent months, with the trend becoming more and more pronounced. Even so, gasoline price wars were raging in several sectors of the coun-

Petroleum Trends . . .



try. This has caused further reductions in refiner margins between what is paid for crude and what is received for products. The margin now has shrunk to a three-year low.

This has had a strong tendency to reduce crude oil prices, which also have been softened by large volumes seeking markets because of heavy cutbacks in producing rates. Consequently, price weaknesses have been increasingly evident in the crude oil market.

Isolated crude price reductions initiated in December have been followed by a growing number of cuts in January and February. Most parts of the country now have experienced downward price adjustments in various types of crude in the past three months.

High inventories, sagging demand, approach of lower consumption in spring months, prospective additional slump in general business, and talk of pipe line proration make the price outlook dim.

Imports need to be cut rather drastically in the immediate future. High imports are an important factor in creating a surplus U. S. supply, since they have not been curtailed in proportion to the slump in U. S. demand and reductions made in U. S. producing and refining volumes.

Despite the government's voluntary program, imports in recent weeks have continued just slightly under all-time peak volumes. Crude oil imports during the four weeks ended February 14 were 131,000 barrels per day greater than in the corresponding period of 1957 although 250,000 barrels below their peak of last August. Refined product imports during the four weeks ended February 14 averaged 61,000 barrels per day more than during the corresponding period of 1957, and 209,000 barrels or 50 percent above last July.

The drastic cuts made in U. S. production would indicate similar reductions should be made in U. S. imports. This action appears essential to the existence of U. S. producers.

A reduction of 200,000 to 250,000 barrels in crude imports to a rate of 750,000 to 800,000 barrels per day, with refined products cut from their recent 630,000 barrels daily level to 450,000 or possibly 500,000 barrels a day, seems not only desirable but to be fair and equitable.

U. S. Crude Production by States

(THOUSANDS OF BARRELS)

STATE or DISTRICT	DAILY AVERAGE PRODUCTION				TOTAL PRODUCTION		
	Jan., 1958	Dec., 1957	Jan., 1957	% Diff. Jan., 1957-1958	Jan., 1958	Jan., 1957	% Diff. 1957-1958
Alabama	15.3	15.6	11.4	+ 34.2	475	354	+ 34.2
Arkansas	83.1	82.8	84.1	— 1.1	2,577	2,606	— 1.1
California	921.0	928.8	938.7	— 1.9	28,551	29,099	— 1.9
Colorado	140.2	143.4	158.5	— 11.6	4,345	4,915	— 11.6
Florida	1.3	1.3	1.3	.....	39	39	.....
Illinois	235.6	239.0	226.1	+ 4.2	7,303	7,010	+ 4.2
Indiana	30.8	31.3	36.0	— 14.5	955	1,117	— 14.5
Kansas	335.5	340.1	333.5	+ 0.6	10,400	10,339	+ 0.6
Kentucky	41.5	42.6	46.5	— 10.8	1,285	1,440	— 10.8
Louisiana	486.3	838.8	997.0	— 15.1	26,235	30,906	— 15.1
North Louisiana	114.6	113.6	139.4	— 17.8	3,551	4,321	— 17.8
South Louisiana	731.7	725.2	857.6	— 14.7	22,684	26,585	— 14.7
Michigan	25.9	27.1	28.5	— 9.2	804	885	— 9.2
Mississippi	105.1	104.0	112.5	— 6.6	3,258	3,487	— 6.6
Missouri—Tennessee	.2	.....	.2	+ 50.0	9	6	+ 50.0
Montana	74.7	74.4	68.5	+ 9.1	2.316	2,123	+ 9.1
Nebraska	54.6	55.5	47.2	+ 15.9	1,694	1,462	+ 15.9
Navada	.2	.1	.1	+ 66.7	5	3	+ 66.7
New Mexico	268.2	262.3	256.0	+ 4.7	8,314	7,937	+ 4.7
Southeast New Mexico	262.3	257.5	251.0	+ 4.3	8,131	7,795	+ 4.3
Northwest New Mexico	5.9	4.8	4.6	+ 28.9	183	142	+ 28.9
New York	6.9	7.1	7.0	— 1.8	214	218	— 1.8
North Dakota	37.1	38.4	41.8	— 11.3	1,149	1,296	— 11.3
Ohio	16.3	16.4	13.1	+ 24.1	504	406	+ 24.1
Oklahoma	568.6	581.1	613.8	— 7.4	17,626	19,027	— 7.4
Pennsylvania	19.6	19.8	22.5	— 12.8	608	697	— 12.8
South Dakota	.2	.1	.1	+100.0	6	3	+100.0
Texas	2,727.5	2,717.5	3,120.3	— 12.6	84,551	96,730	— 12.6
Dist. 1: South Central	46.7	50.2	56.0	— 16.6	1,447	1,736	— 16.6
Dist. 2: Middle Gulf	128.8	130.4	154.3	— 16.5	3,993	4,784	— 16.5
Dist. 3: Upper Gulf	412.6	407.7	460.0	— 10.2	12.792	14,247	— 10.2
Dist. 4: Lower Gulf	203.9	203.6	236.9	— 13.9	6,321	7,342	— 13.9
Dist. 5: East Central	32.3	31.3	39.8	— 18.8	1,002	1,234	— 18.8
Dist. 6: Northeast	284.7	276.1	343.0	— 17.0	8,827	10,638	— 17.0
Dist. 7-B: North Central	146.0	144.2	162.0	— 9.8	4,528	5,019	— 9.8
Dist. 7-C: West Central	151.2	155.0	171.7	— 11.9	4,687	5,322	— 11.9
Dist. 8: West	1,017.8	1,009.5	1,143.9	— 11.0	31,552	35,460	— 11.0
Dist. 9: North	198.7	205.9	209.4	— 5.1	6,160	6,490	— 5.1
Dist. 10: Panhandle	104.7	103.7	101.6	+ 3.0	3,246	3,150	+ 3.0
Utah	15.2	14.1	10.7	+ 41.1	470	333	+ 41.1
Virginia	.....	.....	.....	.....	.....	.....	.....
Washington	.1	.1	.....	.....	1	1	.....
West Virginia	5.8	5.9	5.8	.....	181	181	.....
Wyoming	306.2	307.0	298.8	+ 2.5	9,491	9,262	+ 2.5
Total United States	6,883.0	6,894.6	7,480.0	— 8.0	213,366	231,882	— 8.0

Source: Bureau of Mines and API. Texas Districts from API and do not necessarily agree with State totals.

U. S. Crude Oil and Refined Product Trends

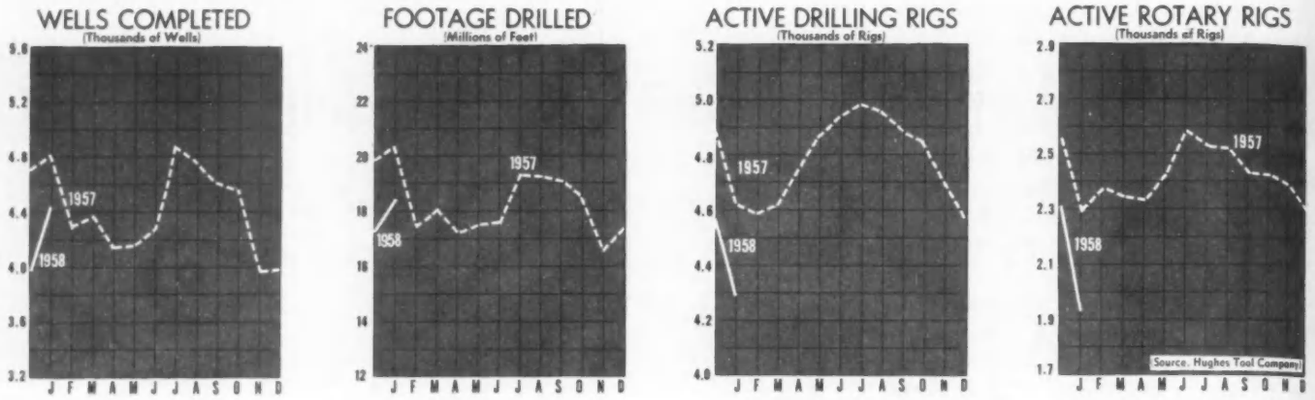
(THOUSANDS OF BARRELS)

MONTH	CRUDE OIL			GASOLINE		DISTILLATE FUEL		RESIDUAL FUEL		DAILY IMPORTS	
	Production Daily	Runs to Stills Daily	Stocks End of Month	Production Daily	Stocks End of Month	Production Daily	Stocks End of Month	Production Daily	Stocks End of Month	Crude Oil	Total Oils
1956:											
January	7,199	8,023	261,592	3,927	183,905	1,923	86,141	1,344	38,247	805	1,422
February	7,208	8,047	259,504	3,854	196,092	1,918	71,335	1,286	35,675	878	1,473
March	7,278	7,914	265,683	3,829	199,698	1,808	60,846	1,213	32,984	934	1,425
April	7,146	7,487	277,121	3,646	193,299	1,713	63,571	1,130	32,740	815	1,308
May	7,064	7,896	277,497	3,859	186,673	1,667	75,928	1,149	36,607	938	1,416
June	7,100	8,071	274,491	3,976	177,076	1,755	93,758	1,098	39,073	987	1,424
July	7,090	8,014	277,008	3,975	176,536	1,767	115,787	1,066	43,958	1,084	1,463
August	7,195	7,995	279,944	4,037	172,939	1,839	137,905	1,091	46,617	1,001	1,399
September	7,054	8,024	278,791	3,991	177,974	1,845	150,411	1,062	47,342	1,043	1,453
October	6,966	7,608	286,560	3,773	172,798	1,772	158,871	1,082	48,400	1,004	1,541
November	7,139	8,031	275,995	3,913	174,808	1,841	151,517	1,182	44,590	871	1,362
December	7,377	8,141	266,014	4,039	187,271	1,981	133,981	1,288	44,491	873	1,471
1957:											
January	7,480	8,274	256,669	3,991	197,702	2,118	100,572	1,322	38,403	805	1,421
February	7,682	8,088	256,344	3,864	205,270	2,035	85,105	1,270	36,201	780	1,430
March	7,717	8,047	254,911	3,826	206,716	1,861	76,245	1,205	37,371	836	1,464
April	7,541	7,740	265,796	3,770	201,407	1,764	78,743	1,132	37,429	906	1,542
May	7,442	7,992	275,963	3,900	195,094	1,789	98,135	1,103	41,125	1,042	1,558
June	7,107	7,867	284,312	3,984	190,063	1,773	117,364	1,101	45,572	1,147	1,606
July	6,873	7,852	288,241	3,887	177,868	1,750	138,359	1,090	49,621	1,220	1,654
August	6,786	8,092	283,388	4,122	174,031	1,806	159,124	1,089	52,645	1,257	1,695
September	6,887	7,920	280,469	4,099	180,688	1,772	173,269	1,100	58,727	1,042	1,445
October	6,860	7,650	284,517	3,939	180,902	1,705	176,388	1,052	60,025	1,022	1,532
November	6,824	7,692	281,769	3,901	187,141	1,734	166,763	1,069	59,622	902	1,544
December	6,895	7,803	276,561	3,935	196,377	1,874	150,769	1,110	59,315	1,045	1,619
1958:											
January	6,883	7,661	280,601	3,832	205,057	1,855	122,325	1,067	57,520	955	1,550
Week Ended:											
2-14-58	6,852	7,520	*278,982	3,794	210,560	1,709	108,417	1,088	57,134	1,217	1,898
2-15-57	7,515	7,976	*251,365	3,761	202,254	2,097	91,385	1,240	35,812	820	1,469

* Previous week's stocks.

Source: Data for last two months from API; prior monthly data from Bureau of Mines.

Drilling Activities . . .



January Completions Fall

8.7% Below Year-Ago Rates

UNITED STATES drilling activity continued its downward trend during January, with 8.7 percent fewer wells than a year ago. There was a total of 4,427 new wells and 18,507,609 feet of hole drilled during the month, compared with 4,849 wells and 20,457,411 feet in January last year.

However, the new year began with more wells and footage than in December 1957, when only 3,974 wells were completed and 17,294,300 feet drilled. This represents an increase of 11.3 percent.

In contrast, the number of rigs in operation does not indicate an immediate gain in future drilling. There were only 4,290 rigs operating at the end of January, 1958, as compared with 4,569 the previous month and 4,625 a year ago. Three states showing an increase in rig operation over December were Oklahoma, Ohio and West Virginia, with a combined total of 53 additional working rigs.

Increased activity was also noted in Oklahoma by completion of 497 wells during January in contrast with only 299 wells completed for December. There was a 20 percent gain shown in completed wells both in Ohio and West Virginia.

Texas followed the general decline pattern of the nation with a decrease of 14.4 percent in wells for this year's beginning compared to that of last year. The decrease of 27 percent activity in the Gulf area represented 99 fewer wells and 620,078 less footage for the period, while the North and North Central Texas showed 103 fewer wells completed with 214,114 less footage. Although those areas did much to reduce the Texas count, the West Texas area was more responsible for the sharp decline noted for the month. Where that district had maintained a lead of more than 15 percent increase each month during 1957 over the peak year of 1956, it dropped to only a 2.3 percent increase to begin this new year.

During the past few months, it has been quite apparent that a greater portion of the drilling activity was in proven areas. The number of wildcats completed continued to decline in January. The 901 wildcats completed in January was a very poor showing as compared to the two previous years. The year of 1956 began with 1,063 wildcats and maintained an average of 1,050 wells per month, while 1957 started with the high of 1,078 completed wildcats but dropped to an average of 949 wells through December. There was a monthly average of 3,816 field wells drilled in 1956 with a correspondingly lower count of 3,497 for 1957.

Western Canada continued its upward pace with an increase of 22.3 percent over the previous year, and 95 more wells for January than in December.

Summary of U. S. Drilling Activity

ITEM	Jan., 1958	Dec., 1957	Jan., 1957	Percent Diff. Jan., 1957-1958
New Wells Completed:				
Oil	2,235	1,862	2,630	— 15.0
Distillate	61	67	53	+ 15.1
Gas	366	295	301	+ 21.6
Service	140	97	81	+ 72.8
Dry	1,625	1,653	1,784	— 9.0
Total Wells	4,427	3,974	4,849	— 8.7
Footage Drilled (Mln. of Feet)	18.5	17.3	20.5	— 9.8

Summary of U. S. Wildcat Drilling

ITEM	Jan., 1958	Dec., 1957	Jan., 1957	Percent Diff. Jan., 1957-1958
New Field Discoveries:				
Oil	67	39	98	— 31.6
Distillate	3	7	15	— 80.0
Gas	28	19	19	+ 47.4
Total Discoveries	98	65	132	— 25.8
Dry Wildcats	803	865	946	— 15.1
Total Wildcats	901	930	1,078	— 16.4
Percent Productive	10.9	7.0	12.2	.....
Percent Dry	89.1	93.0	87.8	.....

U. S. Drilling Activity in January Compared With Year Ago

STATE or DISTRICT	NEW WELLS COMPLETED AND FOOTAGE DRILLED: DETAILS FOR JANUARY: Oil	Dist.	Gas	Dry	Service Wells	TOTAL NEW WELLS: Jan., 1958	Dec., 1957	Jan., 1957	% Diff. Jan., 1958-1957	TOTAL FOOTAGE: January 1958	January 1957	WILDCAT DRILLING IN JANUARY: NEW FIELDS IN JANUARY: Oil	Dist.	Gas	TOTAL DISCOVERIES: Jan., 1958	Dec., 1957	Jan., 1957	DRY WILDCATS: Jan., 1958	Dec., 1957	Jan., 1957	TOTAL WILDCAT TESTS: Jan., 1958	Dec., 1957	Jan., 1957	DRILLING RIGS IN OPERATION: Jan., 31 1958	Dec., 31 1957	Jan., 31 1957
Alabama	2			2		4	6	2	+100.0	39,723	23,071							2	3		2	3		11	11	20
Arizona				1		1			+100.0	590								1			1			6	5	1
Arkansas	49		2	18		69	86	115	— 40.0	209,250	315,919			1	1	2	1	9	21	11	10	23	12	41	46	66
California	129		5	47		181	205	209	— 13.4	774,449	968,700	1			1	1	2	24	41	38	25	42	40	160	168	177
Colorado	17		11	39		67	70	86	— 22.1	337,550	425,881	6		2	8	5	3	29	33	51	37	38	54	54	50	57
Florida							1	1			12,219								1	1		1	1	1	1	2
Georgia																										1
Idaho								1			3,947									1			1			1
Illinois	92		1	123	2	218	124	216	+ 0.9	481,667	506,016	1			1	1	2	53	30	56	54	31	58	240	268	277
Indiana	18		1	33		52	69	72	— 27.8	86,943	123,037							17	18	16	17	18	16	105	117	110
Kansas	137		16	134	9	296	409	358	— 17.3	1,056,646	1,325,747	3		1	4	5	19	63	89	64	67	94	83	500	515	510
Kentucky	40		12	63	2	117	120	117		181,593	188,380	1		1	2	1	3	8	4	3	10	5	6	84	86	93
Louisiana	146	19	27	125		317	291	291	+ 8.9	2,553,827	2,666,558	4	1	1	6	6	7	34	47	44	40	53	51	366	381	412
North Louisiana	65	1	11	30		107	113	140	— 23.6	431,235	483,803	1			1	2	2	4	22	14	5	24	16	77	82	67
South Louisiana	81	18	16	95		210	178	151	+ 39.1	2,122,592	2,182,755	3	1	1	5	4	5	30	25	30	35	29	35	289	299	345
* Gulf of Mexico	27	3	3	12		45	45	39	+ 15.3	420,516	354,553						1	3	3	3	3	3	4	62	69	87
Maryland																										
Michigan	9		3	12		24	52	35	— 31.4	72,069	112,081			1	1	3	1	7	17	15	8	20	16	55	66	57
Mississippi	14	2		26		42	30	27	+ 55.6	352,419	198,480	2			2		3	19	10	11	21	10	14	44	44	29
Missouri																				1			1			1
Montana	17		2	18	1	38	37	37	+ 2.7	226,767	191,278	3		2	5	1		14	19	10	19	20	10	36	42	31
Nebraska	15			32		47	75	85	— 44.7	289,842	507,134	4			4	2	5	10	31	43	20	33	48	22	27	29
Nevada								1			3,386									1			1	1	1	3
New Mexico	136		71	46	1	254	145	221	+ 14.9	1,151,561	976,897	3		8	11		4	30	22	27	41	22	31	170	175	152
New York	21		1	2	24	48	48	33	+ 45.5	73,800	58,300													44	46	57
North Dakota	23			8		31	49	26	+ 19.2	198,419	179,486	2			2	4	2	4	24	9	6	28	11	45	45	22
Ohio	48		19	21		88	73	75	+ 17.3	233,956	186,220							2		2	2		2	226	203	218
Oklahoma	253	6	31	173	34	497	299	609	— 18.4	1,772,184	2,096,876	4		4	8	6	14	47	32	51	55	38	65	610	585	558
Oregon																								1	1	
Pennsylvania	35		18	9	34	96	109	74	+ 29.7	205,830	189,142			1	1		2			2	1		4	108	140	162
South Dakota				3		3		2	+ 50.0	16,991	10,797							3		2	3		2		2	5
Texas	968	34	97	616	33	1,748	1,510	2,041	— 14.4	7,455,058	8,705,622	31	2	6	39	26	58	379	387	464	418	413	522	1,050	1,230	1,288
Dist. 1: South Central	32		13	34		79	84	138	— 42.8	227,584	387,382	3			3		4	25	34	40	28	34	44	32	37	50
Dist. 2: Middle Gulf	15	11	4	18		48	52	67	— 28.4	303,125	422,482	2	1	1	4	2	3	8	18	23	12	20	26	38	36	40
Dist. 3: Upper Gulf	63	10	6	51		130	117	179	— 27.4	847,264	1,250,244	1		1	2	3	9	28	29	48	30	32	57	94	109	140
* Gulf of Mexico								4			31,433						1			2			3	1	1	1
Dist. 4: Lower Gulf-S.W.	29	10	5	51		95	123	126	— 24.6	543,204	640,945	3		1	4	1	4	40	50	41	44	51	45	57	77	77
* Gulf of Mexico							2	1			8,710								1			1		1	1	4
Dist. 5: East Central	1		2	22		25	27	16	+ 56.3	93,904	96,847					1	2	15	22	11	15	23	13	5	11	10
Dist. 6: Northeast	51	1	5	41		98	86	104	— 5.8	518,988	555,488	2			2	1		21	30	20	23	31	20	46	60	71
Dist. 7-B: North Central	112		4	100	1	217	173	261	— 16.9	708,527	908,321	4			4	4	11	67	67	56	71	71	67	97	111	120
Dist. 7-C: West Central	56		1	34		91	68	122	— 25.4	448,960	533,569	2			2	1	5	26	14	38	28	15	43	70	77	99
Dist. 8: West	314		5	69	9	397	438	387	+ 2.3	1,855,763	2,054,850	6			6	10	8	48	55	46	54	65	54	314	368	319
Dist. 9: North	230	2	22	171	23	448	233	507	— 11.6	1,316,152	1,330,472	7	1	1	9		8	85	59	132	94	59	140	184	227	251
Dist. 10: Panhandle	65		30	25		120	109	134	— 10.5	591,587	525,022	1		2	3	3	4	16	9	9	19	12	13	113	117	111
Utah	26			14		40	36	9	+344.4	228,555	52,469						1	7	7	2	7	7	3	60	64	38
Washington				1		1			+100.0	8,400								1			1				1	
West Virginia	9		47	13		69	57	53	+ 30.2	180,002	149,844						2		1	2		1	4	173	168	182
Wyoming	31		2	46		79	73	53	+ 49.1	319,518	279,924	2			2	2	3	34	28	19	36	30	22	77	75	66
Total United States	2,235	61	366	1,625	140	4,427	3,974	4,849	— 8.7	18,507,609	20,457,411	67	3	28	98	65	132	803	865	946	901	930	1,078	4,290	4,569	4,625
Total Western Canada	193		15	66		274	179	224	+ 22.3	1,759,320	1,012,681													196	177	196

* Gulf of Mexico wells are included in their respective district totals.

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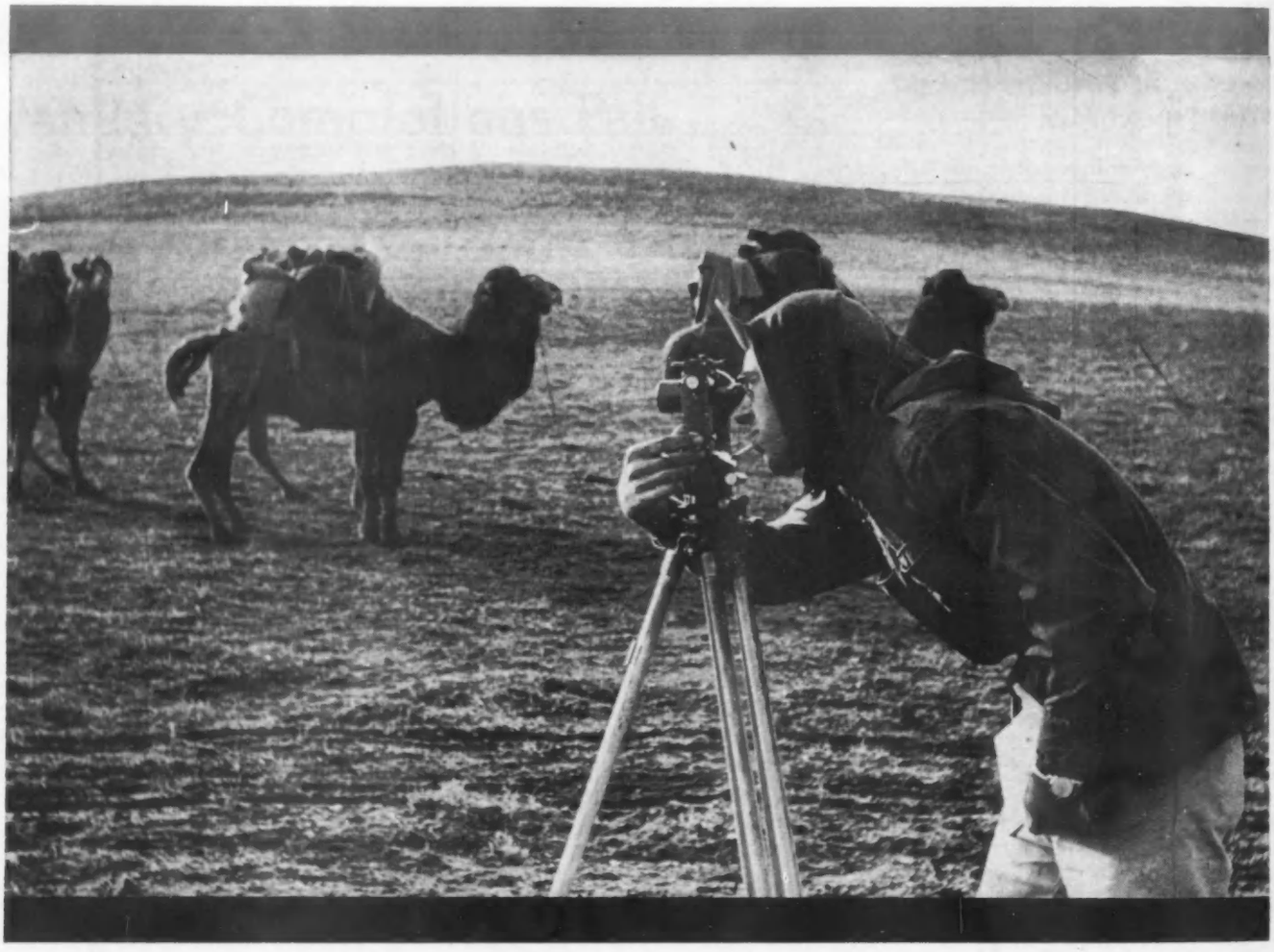

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New Slide Rule Simplifies Electric Log Quantitative Analysis

This compact calculator provides all corrected basic data and instantly solves all equations for analysis of all electric logs.

By Dr. R. G. Hamilton
Hamilton Well Log Consultants, Tulsa

A NEW SLIDE rule calculator for rapid, quantitative analysis of electric logs has been designed for the log analyst. Essentially, the slide rule rapidly solves quantitative as well as empirical relationships used to obtain percent porosity, percent water saturation and, in some cases, estimates of permeability. It utilizes data from the spontaneous potential curve, resistivity curves and the micro curves of electric logs of any of the well logging companies as well as data from the induction log, the limestone curve, the Laterolog, the guard log, the focus log, the Microlaterolog or its equivalent, and neutron logs.

Although fully comprehensive in its interpretations, the slide rule fills the needs of the beginner as well as those of the advanced log specialist. Both the generalized quantitative relationships and the specialized equations having variable coefficients and exponents are provided. These are color-coded for easy use and distinction.

This new, compact slide rule calculator makes it possible to obtain almost instantly the following information required in quantitative electric log analysis:

(1) Specific gravity and grains per gallon NaCl @ 68° F. for any value of Rw or parts per million NaCl.

(2) Parts per million, NaCl, for any value of Rw or Rmf from 32° F. to 300° F.

(3) Correction of Rm, Rmf and, or, Rw from a measured temperature to any other temperature up to 300° F.

(4) Determination of Rmf and Rmc, according to published average data, for the Rm determined at a given temperature.

(5) Determination of Rw for equivalent parts per million NaCl from a chemical analysis of formation waters.

(6) Instant plotting of Rm, Rmf and Rmc values at any depth on a log from temperature gradient scales alone.

(7) Rwe and the corrected figure for Rw for any depth in the borehole, from the S.P. equation. Instant evaluation of Rmf/Rwe for use with other quantitative methods.

(8) Sw% by the $(Ro/Rt)^{1/n}$ method for n from 1.4 to 2.4.

(9) Ro and Sw using the Humble or Archie formation resistivity factor relationships and for "m" values from 1.6 to 2.4.

(10) Instant determination of ∅ from hydraulic pad micro curve data.

(11) Instant determination of ∅ by the microlog empirical method.

(12) Instant determination of ∅ by the limestone or short normal methods.

(13) Sw determination by the Rocky Mountain method.

(14) ∅ determination by the Rocky Mountain method.

(15) Estimation of k, permeability, above the transition zone.

(16) Multiplication and division without an engineers' slide rule.

In the beginning of their quantitative studies, many geologists and engineers prefer nomograms for solution of various relationships despite the fact that this requires a large notebook of charts. The analyst eventually desires to increase accuracy and to materially reduce the time required for routine and somewhat boring but necessary steps. Some soon resort to the engineers' slide rule only to discover that this does not provide the flexibility and speed desired.

The new compact slide rule calculator described here is designed to supplant the notebook of nomograms, to vastly accelerate the calculations,

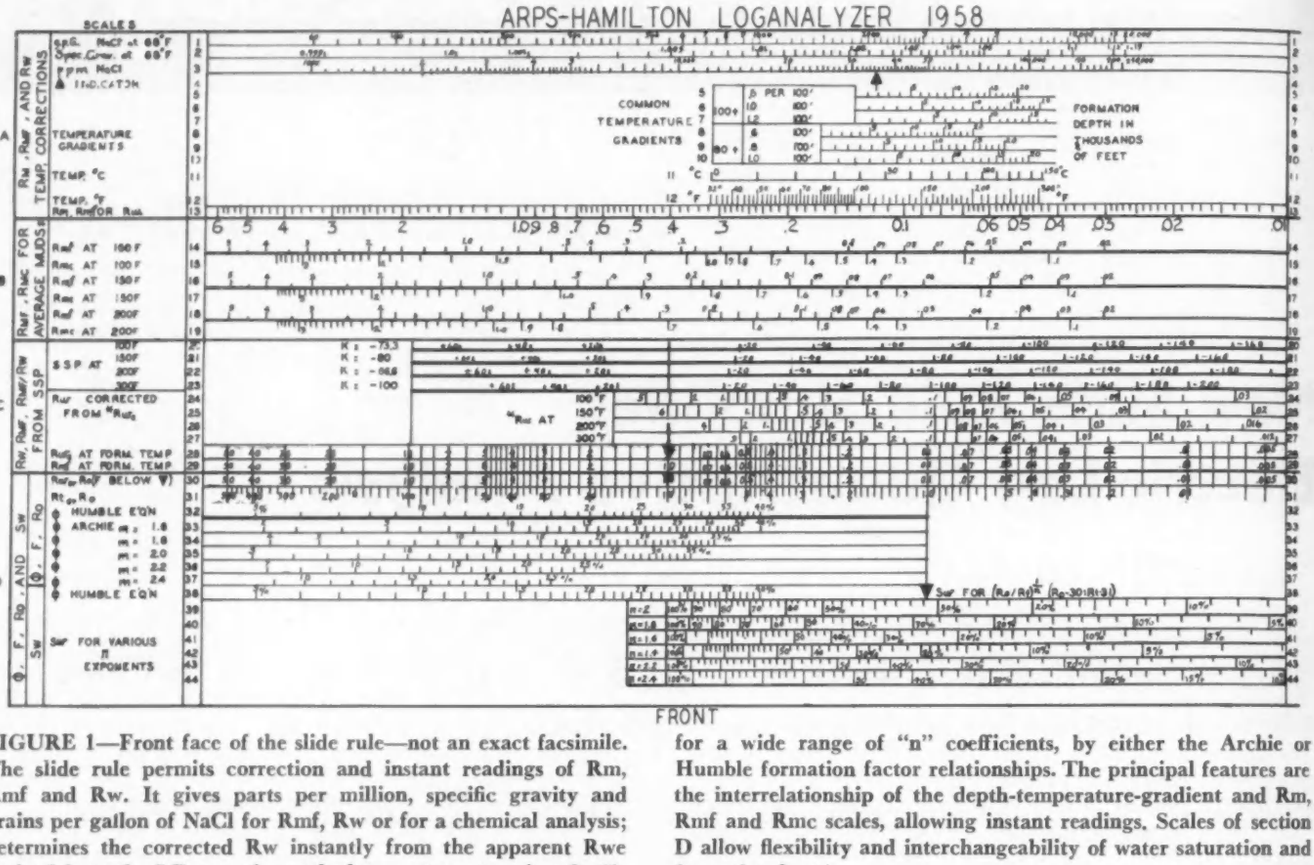

FIGURE 1—Front face of the slide rule—not an exact facsimile. The slide rule permits correction and instant readings of Rm, Rmf and Rw. It gives parts per million, specific gravity and grains per gallon of NaCl for Rmf, Rw or for a chemical analysis; determines the corrected Rw instantly from the apparent Rwe derived from the S.P. equation; calculates water saturation, Sw%, for a wide range of "n" coefficients, by either the Archie or Humble formation factor relationships. The principal features are the interrelationship of the depth-temperature-gradient and Rm, Rmf and Rmc scales, allowing instant readings. Scales of section D allow flexibility and interchangeability of water saturation and formation factor.

and more important, to increase accuracy. Component parts of the tool have been used and tested for a number of years and the new slide rule represents a merging of ideas derived from extensive experience.[1]

It has been found that the present slide rule, with only a few S.P. and resistivity curve corrections charts, permits the solution of 90 percent to 100 percent of the problems of quantitative analysis and that it may be used on the rig floor as well as in the office.

The slide rule is completely modernized to include the most recent concepts in quantitative electric log analysis. It features scales for the instantaneous correction of Rm, mud resistivity, and Rmf, mud-filtrate resistivity, from the measured temperature to the temperature at any depth in the borehole. Corrected values are obtained in second through a combination of borehole temperature gradient scales and resistivity scales. At the same time, corresponding values of Rmc and Rmf are read instantly at the formation temperature. An important feature is the instant visual determination of Rw, formation water resistivity, from the equivalent or apparent Rwe figure derived from the S.P. equation. Both the Archie and Humble formation resistivity factor relationships are available and two methods permit the ready determination of percent formation water saturation for "n" saturation exponents from 1.4 to 2.4.

A feature greatly appreciated by those who have used the rule is the almost instantaneous determination of percent porosity for 0 percent to 50 percent residual oil saturations from hydraulic pad micro curve data, reducing the time ordinarily required to one-tenth or less. The same scales are used for porosity estimation from the Microlaterolog and its equivalent tool or from any derived value of Rxo/Rmf.

Description of Slide Rule. Figures 1 and 2 portray the front and back sides of the calculator but cannot, of course, show all of the data on the moveable slide. The slide rule is constructed of durable vinylite plastic reinforced with nickel eyelets. It weighs about three ounces; the dimensions being 4 inches x 10 inches. There is one moveable slide and a cursor or hairline runner with some windows having fixed vertical hairlines. The unique combination of the cursor and the fixed hairlines permits speedy solution of some equations and the direct reading of certain empirical data related to another datum. This combination provides versatility and multiple usages of common scales. The slide rule has 76 scales grouped appropriately into sections A, B, C, D, E, F, and G. The sections are arranged in the order of systematic steps usually followed by the analyst; each section provides information necessary for the step involved in the following section. Standard API and AIME log symbols identify the scales and corresponding definitions are given on the left sides of the moveable slide. Equations utilized in the quantitative solutions of each section are printed on the right sides of the moveable slide. Thus, it is not necessary for the analyst to refer constantly to definitions or equations in a textbook or notebook of charts; everything required for reference is available on the slide rule.

Solution of Quantitative Equations and Empirical Relationships.

Front Side (Figure 1)—Section A: This section allows the following rapid computations and determinations: grains per gallon NaCl @

68° F., specific gravity of NaCl @ 68° F., parts per million NaCl, mud resistivity Rm, mud-filtrate resistivity Rmf, formation water resistivity Rw, all at any temperature from 32° F. to 300° F. or the equivalent in degrees centigrade. In addition, depth scales for temperature gradients of 100° F. plus 0.8, 1.0, 1.2 degrees per 100 feet of depth and 80° plus 0.6, 0.8, 1.0 degrees per 100 feet of depth are indexed. One can read, directly below the depth lines, Rm, Rmf or Rw, corrected from surface or laboratory temperature measurement. The operator simply sets Rm opposite the measured temperature slides the cursor to the appropriate depth line of the appropriate gradient scale and reads the corrected values instantly. An arrow index points to the ppm., specific gravity and grains per gallon values corresponding to each setting of the cursor.

Tables on the right side of the slide make possible conversion of grains per gallon and specific gravity @ 68° F. to other temperatures.[2] The Dunlap[3] conversion factors for converting ppm of each ion reported in a chemical water analysis to equivalent NaCl are also available on the right side of the moveable slide. Thus, chemical analyses of waters containing ions other than Na and Cl may be converted to equivalent NaCl and then to the equivalent Rw value for any temperature.

Section B: This section gives Rmf and Rmc at temperatures of 100°, 150° and 200° F. These data correspond to equivalent Rm values of section A and are read instantly beneath the cursor that was previously set on the Rm figure. The Rmf and Rmc data are average figures reported by Schlumberger.[4] In many cases the analyst may prefer to use field measured data for these parameters.

Some experts have their own preferred ratios of Rmf/Rm and Rmc/Rm determined through laboratory measurements. If desirable, the Rmc and Rmf data may be plotted on a plastic overlay strip to correspond with the Rm scale of the slide rule; thus the speed feature of the slide rule is retained.

Section C: This section solves the S.P. equation to obtain either Rwe, Rmf or the ratio, Rmf/Rwe. The equation is as follows:

$$SSP\,(Ec) = -K \log_{10} (Rmf/Rwe);$$

where $K = (60 + 0.133 \times T°F)$ Electrochemical K and the SSP values are provided on scales for temperatures of 100°, 150°, 200° and 300° F. The SSP scales are indexed for each —10 millivolts, and interpolation between any two adjacent SSP temperature scales is readily made.

The SSP value for a formation is placed under a fixed window hairline by moving the slide. The Rwe figure is read instantly opposite the previously determined Rmf figure. Immediately above the Rwe figure thus determined, the analyst reads the corrected Rw figure for the same formation temperature. The Rw and Rwe data are those average values recently published by Gondouin et al.[5] A similar operation determines Rmf when Rw is known. Rmf/Rwe is always directly indicated below an arrow index as the slide is moved for values of SSP or for settings of Rmf and Rwe on the scales.

Section D: This section solves the Archie[6,7] relationship for water saturation, Sw, and the Archie and Humble relationships for formation resistivity factor, F, Ro and ∅, percent porosity. The equation follows:

$Sw = (Ro/Rt)^{1/n}$, where "n" is 1.4, 1.6, 1.8, 2.0, 2.2 or 2.4

$Ro = F \times Rw = 0.62 \times Rw/\phi^{2.15} = Rw/\phi^{m}$, for "m" = 1.6, 1.8, 2.0, 2.2, 2.4

$Sw^{n} = Rw/\phi^{m} \times Rt = 0.62 \times Rw/\phi^{2.15} \times Rt$

Some scales are interchangeable and two solutions for Sw are available:

(1) Ro is calculated from ∅ and Rw by either the Archie or Humble formation factor relationship. The value ∅ is placed beneath a fixed vertical hairline, and Ro is read directly opposite Rw on an adjacent scale. The percent porosity, ∅, may be placed on a scale for the Humble relationship or on a scale for the Archie relationship for any "m" value. Rt, true resistivity, is then placed opposite the calculated Ro value and water saturation, Sw, is read directly below an arrow index for any "n" value desired.

(2) Ro does not need to be calculated. Rt is placed opposite the Rw determined from Section C or from water data. The cursor is then placed over the ∅ value on either the Humble or Archie porosity scales. Sw is read directly under the hairline of the cursor on the Sw scales for any "n" value desired. The combination of scales in Section D permits extreme flexibility and multiple calculations. This combination shows the log analyst what magnitude of Rt is required for given values of Rw, ∅ and Sw%. Practice with this portion of the new slide rule gradually develops a familiarity with quantitative electric log analysis that cannot be acquired in any other way.

Back Side (Figure 2)—Multiplication and Division: Full length logarithmic scales are provided for these operations.

Section E: Percent porosity is determined in this section by three methods:

(1) Hydraulic pad micro curve data. Percent porosity is determined from Rxo/Rmf by the following equation:

$$\phi = \left[\frac{0.62 \times Rmf/Rxo}{(1 - ROS)^2}\right]^{1/2.61}$$

The R1″ xl″/Rmc and R2″/Rmc data from the micro curves are placed opposite one another by moving the slide. Rxo/Rmc is read directly under the window hairline. This value, on a nonlogarithmic scale, is transferred to a logarithmic scale. The cursor is placed over Rmc of the Rmc scale. The slide is then moved to the left to place Rmf under the hairline of the cursor. ∅ is then read directly opposite values of ROS from 0% to 50%, and the entire operation requires only seconds. Rxo/Rmf data from a Microlaterolog are simply entered on the Rxo/Rmf scale and the same procedure is followed to obtain percent porosity.

(2) Porosity by the microlog empirical method[8]: The value of R2″ from any log with micro curves is placed opposite the Rm value and percent porosity is read opposite the arrow index. The method, of course, is subject to possible errors described on chart C-2 of the Schlumberger log interpretation charts.[8]

(3) Porosity from the limestone curve and short normal curves: The porosity index method of Tixier[9] is used. Ri/Rm from the limestone or short normal curve is placed under a vertical hairline in the window. Percent porosity is read directly opposite the SSP for the formation. SSP scales are provided for oil and for water bearing formations. An additional correction scale indexed from 0.1 to 2.0 is available for use by experts who

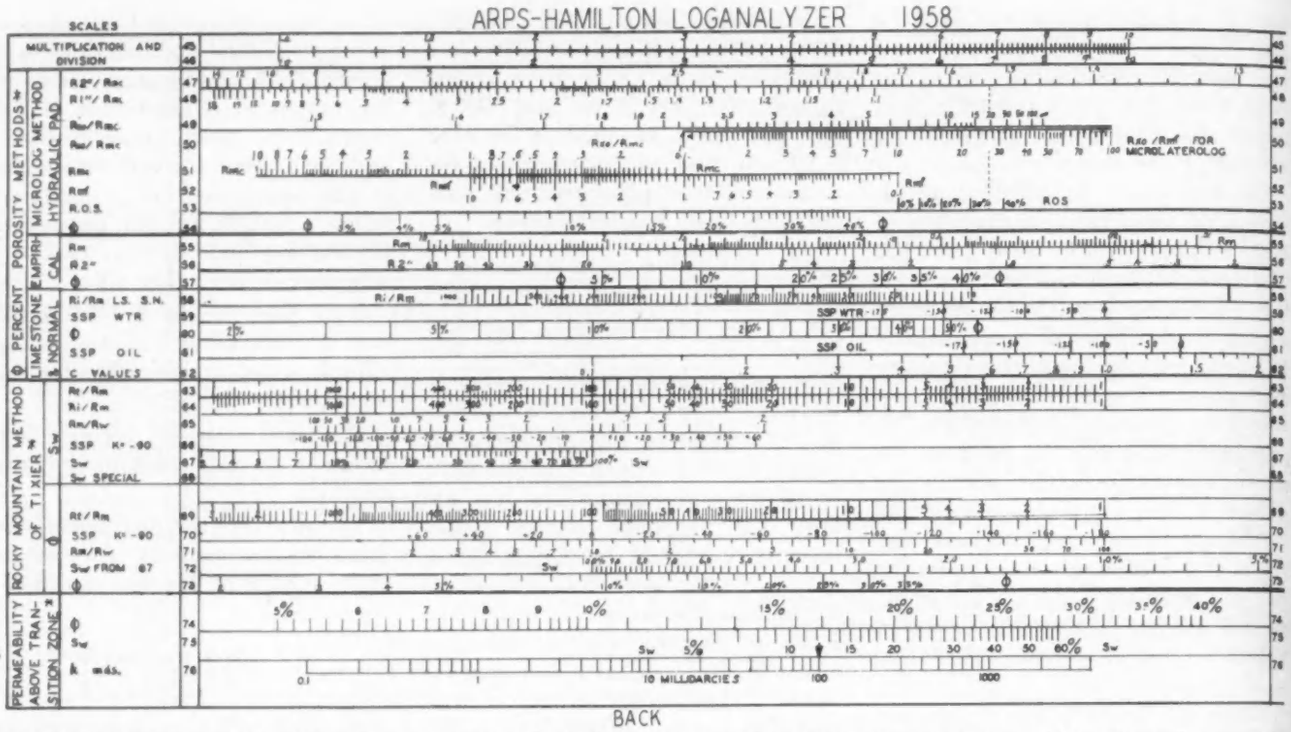

FIGURE 2—Back face of the slide rule—not an exact facsimile. The rule permits multiplication and division. It determines percent porosity from hydraulic pad micro curves by microlog empirical method and by the limestone and short normal methods. Water saturation and percent porosity are determined by the Rocky Mountain method and permeability above the transition zone may be estimated by the Schlumberger relationship.[11] Features include speed for porosity determinations, extra scales for Sw% in the Rocky Mountain method and multiplying constants in the limestone porosity method.

prefer to use corrections somewhat different than those provided by the SSP values for oil and water. The method is based upon the equation:

$\phi = C_{SSP} \times (Rm/Ri)^{1/2}$, where values of the SSP, in millivolts represent multiplying constants.

Without the use of the SSP multiplying constants an apparent porosity or porosity index would be obtained. The SSP constants correct for the degree of invasion and flushing in the invaded zone and for the mixture of fluids in oil and water-bearing formations. The method is designed for rocks of moderate and low porosities where Ri/Rm is preferably greater than 20 or 25.

Section F: This section determines Sw and ∅ by the Rocky Mountain method:[10]

(1) Sw determination: Ri/Rm from a corrected short normal curve is placed opposite Rt/Rm determined from resistivity curves. Sw% is read directly opposite the SSP of the formation. The SSP of the slide rule has been indexed for a K of —90 but an additional scale gives values of Rm/Rw; thus the analyst can employ the latter to obtain any equivalent K factor desired. The slide rule solves the following equations:

$$Sw = \frac{Ri/Rt}{Rz/Rw} \text{ in which:}$$

$$Rz/Rw = \frac{10^{SSP/K}}{(1 - 0.075) + 0.075 \times 10^{SSP/K}}$$

The Sw scale of the slide rule is scaled for Tixier's[10] original relationship, $Si^2 = Sw$. Some analysts prefer to use exponents other than 2, and scale 68 of the slide rule is left blank for the insertion of an overlay for such Sw indices.

(2) ∅ determination: To obtain percent porosity, the same value of SSP used above is placed opposite the Rt/Rm scale by moving the slide. ∅ is read directly opposite Sw% (as determined above) on the Sw scale. Again, a Rm/Rw scale is provided to permit the use of this parameter for any desired K factor.

Section G: In this section an estimate of permeability in the zone above the transition zone is obtained: The empirical method outlined by Wyllie and Rose and the specific empirical equation of Schlumberger[11] are used for the scales:

$$k^{1/2} = 250 \times \phi^3/Sw$$

Sw and ∅, as obtained by one of the methods described above, (but only for the zone above the transition zone), are placed opposite one another by moving the slide. Permeability, k, in millidarcies, is read directly below an arrow index.

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ACKNOWLEDGMENT

The writer wishes to give special credit to J. J. Arps for the combination of resistivity-salinity-temperature scales used in section A of the new slide rule and for the ingenious combination of scales in section G that permits instantaneous determination of porosity from micro curves. His suggestions for the lay-out of the slide rule have been invaluable. The writer is indebted to G. E. Archie, M. P. Tixier and M. R. J. Wyllie for certain fundamental concepts that underly electric log quantitative analysis, as well as to others referred to in the references. The writer wishes to thank Schlumberger Well Surveying Corporation for permission to use certain original data; indicated directly on the new tool. The release of certain correction charts by Perforating Guns Atlas Corp. for use in the Handbook of Instructions is also appreciated.

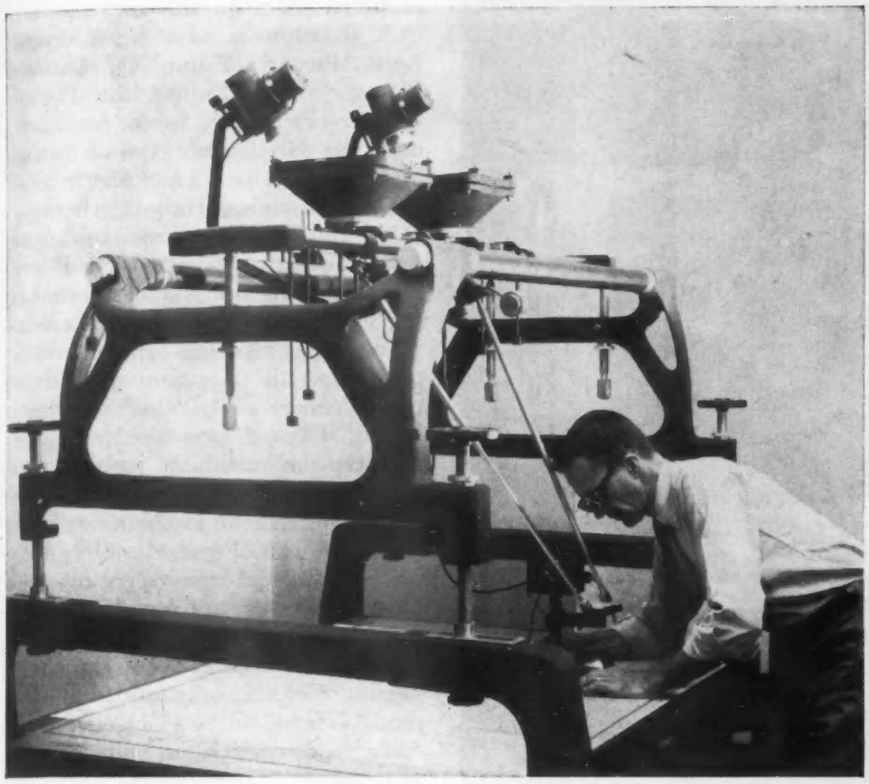

FIGURE 1—Kelsh plotter.

Quantitative Photogeology—Popular Exploration Tool

Geological data obtained through quantitative photo geology are used in the preparation of structural maps, profiles, isopach maps and in hydrodynamic studies.

By Laurence Brundall, Vice President, and **Vernon Jackson,** Senior Geologist, Geophoto, Inc., Denver

PHOTOGEOLOGY is no longer a novelty. Since 1946, when the method began its growth as a widely used exploration tool, the sum total of photogeologic projects undertaken by oil company departments, government agencies, consulting organizations and individuals amounts to more than four million square miles. However, the greatest use of photogeology to date has been qualitative. This would include: (a) broad regional interpretation using small scale photography, (b) more detailed evaluation using medium scale photography, (c) extremely detailed interpretation using large scale coverage and (d) geomorphic interpretation. The term "qualitative" is used to indicate that the photogeologic evaluation provides valuable data on stratigraphy and structure, but the interpretation is limited to estimates of measurable geologic phenomena, such as thickness of section, degree of dip, displacement of faults and amount of structural closure.

Photogeology is now following the course of all exploratory methods in that it is being continually refined. The use of high-order plotting instruments is an example of this refinement. The type of instrument most satisfactory for quantitative geologic work has only become available within the past several years, although either ultra-precise and expensive instruments or cruder and less precise devices have been available for a longer time.

All photogrammetric instruments are based on the principle of parallactic displacement. One component of parallax is a measure of relief while another component is a measure of the relative orientation of the two successive air photo exposures.

The relief component of parallax is measured on two successive overlapping air photos. Stereoscopic examination of the two vertical photographs is made possible by these differences of parallax. Precise measurement of these differences by various plotting instruments results in the accurate determination of elevations and contours.

The most common and easiest method of parallax measurement is by means of the floating dot in a stereoscopic model. By micrometer adjustment the floating dot can be controlled up or down within the model. In a stereoscopic model where the effect of tip and tilt of the camera has been corrected, it is possible to read elevations of features in the model by bringing the floating dot in register with the feature. Topographic maps can be prepared or "spot" elevations can be determined in this manner. Contours may be plotted directly at the scale of the model, or at a smaller scale by means of a pantograph. Spot elevations can be read with a greater accuracy than contour intervals.

There are two main types of instruments which utilize the floating dot within the stereoscopic model:

1. Those instruments in which an overlapping pair of air photographs is viewed either through a simple stereoscope or through optical and/or mechanical linkages in varying degrees of complexity. Instruments of this type range from the simple parallax-bar type through high-order of accuracy plotting instruments with complex optical and/or mechanical linkages.

2. Instruments which use the anaglyphic projection of one or a series

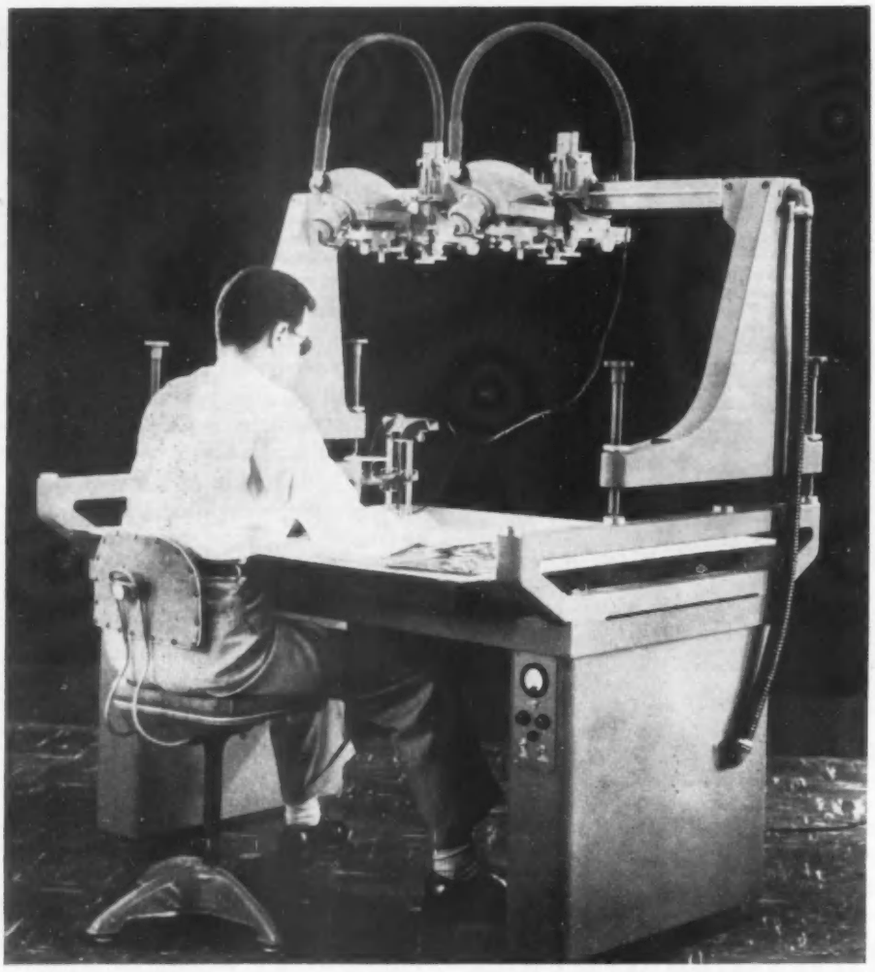

Photo courtesy Bausch and Lomb Co.

FIGURE 2—Balplex plotter. A single model set-up is shown although a longer bar and additional projectors can be used.

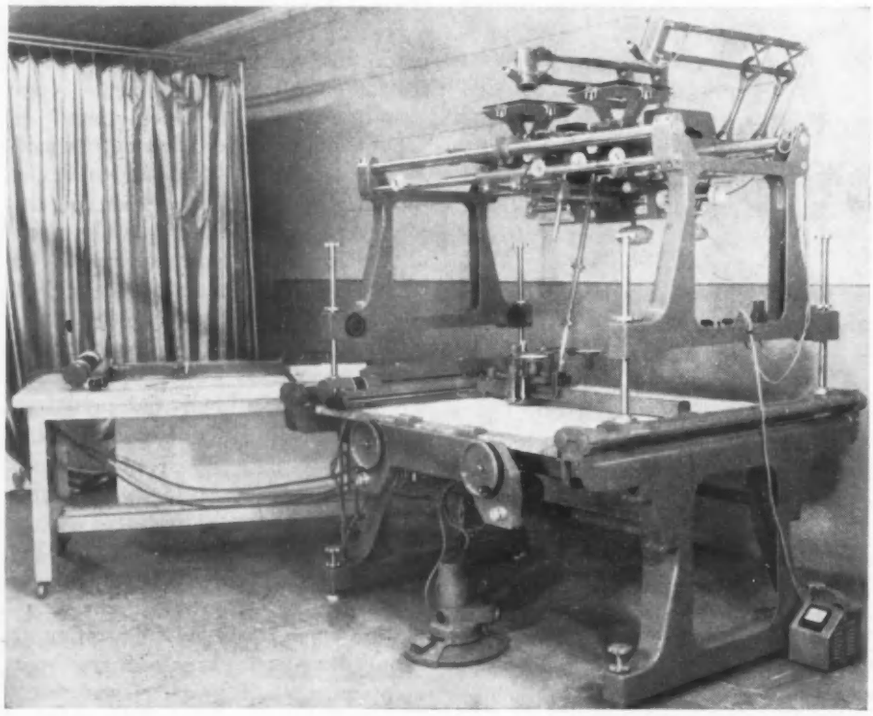

Photo courtesy O.M.I. Corp.

FIGURE 3—Nistri photomapper and electro-coordinatograph. Note the single rod coupling.

of stereo pairs. In this category are such instruments as the Multiplex, Kelsh Plotter (Figure 1), Balplex Plotter (Figure 2) and the Photomapper (Figure 3). In the first category, the parallax-bar type of instrument is simple to operate and is relatively inexpensive. However, because of the comparatively large number of vertical control points needed per model and the necessity of constructing a correction graph for each model plus the fact that this type of instrument can only produce a spot elevation accuracy of 1/250 of the flight height, it is not considered adequate to meet the minimum requirements for quantitative photogeology. A more refined instrument in this category is the Stereotope (Figure 4). Only four or five vertical control points per model are necessary for this instrument; the accuracy of the instrument is stated to be 1/2,000 of the flight height. Correct orientation of the model is achieved by an ingenious use of computers which are built into the instrument. This instrument would be suitable for determination of spot elevations on Rocky Mountain type structures, but its accuracy is not considered sufficient for spot elevation determination in low dip areas without the use of expensive low altitude photography.

Since the anaglyph type of projector is best suited for quantitative geologic work, a brief description of the basic principles of this type of instrument is given. Positive reproductions on glass plates (diapositives) are made either by contact printing or by reduction. These diapositives are set up within the projectors. By utilization of vertical ground control points, the projectors are adjusted in space to coincide with the position of the camera at the time of the original negative exposure. In this manner, each projector becomes a replica of the taking camera. Alternate red and blue light is projected through the diapositives onto a pure white surface. When viewed through spectacles with corresponding red and blue lenses, a three dimensional model of the terrain is observed. Elevation determination in the model is made with a tracing table in the center of which is a small aperture illuminated from beneath. This serves as a floating mark and its height within the model can be adjusted up or down with a dial counter registering the amount of vertical movement. This vertical

movement can be expressed in fractions of a millimeter. The data is then mathematically converted to elevations in feet or meters or, by a series of interchangeable gears, it can be expressed directly in feet or meters. When the floating dot is brought into contact with the terrain surface, its height represents the elevation of the terrain at that point. Contours and planimetric detail may be drawn to the scale of the projected model by a pencil mounted on the tracing table; or, by a pantograph or electroplotting device, these data may be directly reduced to final map scale.

A number of either Multiplex or Balplex type projectors may be set up on a single bar so that continuous series of overlapping stereo pairs can be projected and bridging can be accomplished between widely separated control points. This bridging technique can also be used with higher order instruments and permits the development of control for individual models from widely separated control points obtained by field methods.

The disadvantage of the Multiplex for quantitative photogeology is that the diapositive (size 55mm) is enlarged 12X which creates loss of detail. In addition, the Multiplex model is only enlarged 2.34X the original exposure. The model is also not as well illuminated as in other instruments.

The Balplex Plotter also uses a reduced diapositive, but its size (110mm) is appreciably greater than that of the Multiplex diapositive and, therefore, a clearer model projection is achieved which is further improved over the Multiplex by better illumination. The Balplex model is 3.4X the original exposure. The instrument provides flexibility since it can be used as a single model set-up or a series of models can be bridged for control extension.

There are two anaglyph projection plotters which utilize full scale contact diapositive plates: the Kelsh Plotter and the Nistri Photomapper. A schematic diagram of the principles involved in this type of plotter is shown in Figure 5. The Kelsh Plotter, invented by Harry Kelsh, formerly of the U. S. Geologic Survey, is the original instrument of this type. The Nistri Photomapper is generally similar to the Kelsh except that, instead of a double rod design used in the Kelsh for motivating the projection light source, the Nistri instrument uses a single rod coupling. The Nistri instrument can be coupled to an electrocoordinatograph so that all movements of the tracing table are transmitted electrically to a plotter mounted on a separate table. This plotter can be set to any desired reduction scale and can also be used to reflect the vertical motion of the tracing table so that a topographic profile is drawn as the tracing table moves up and down in the topography along a line of section. Spot elevations on the contact diapositive instruments can be determined to an accuracy of 1/5,000 of the flight height although, under ideal conditions, it might be possible to obtain an accuracy of 1/7,500 of the flight height.

In all photogrammetric plotting in-

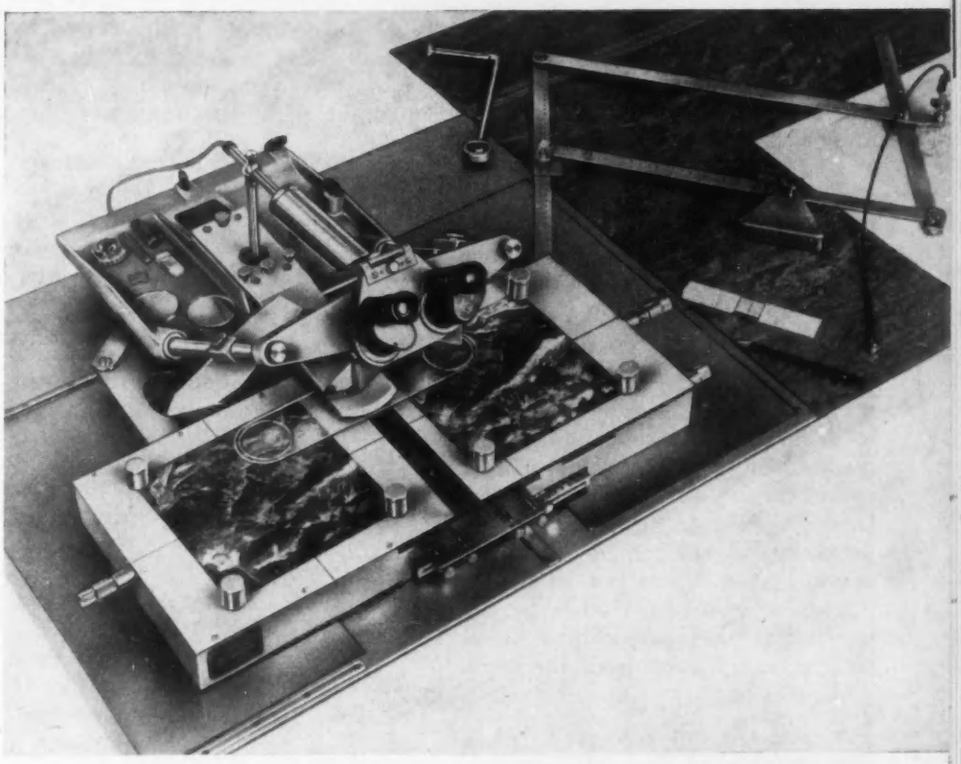

Photo courtesy Transmares Corp.

FIGURE 4—Zeiss sterotop with pantograph.

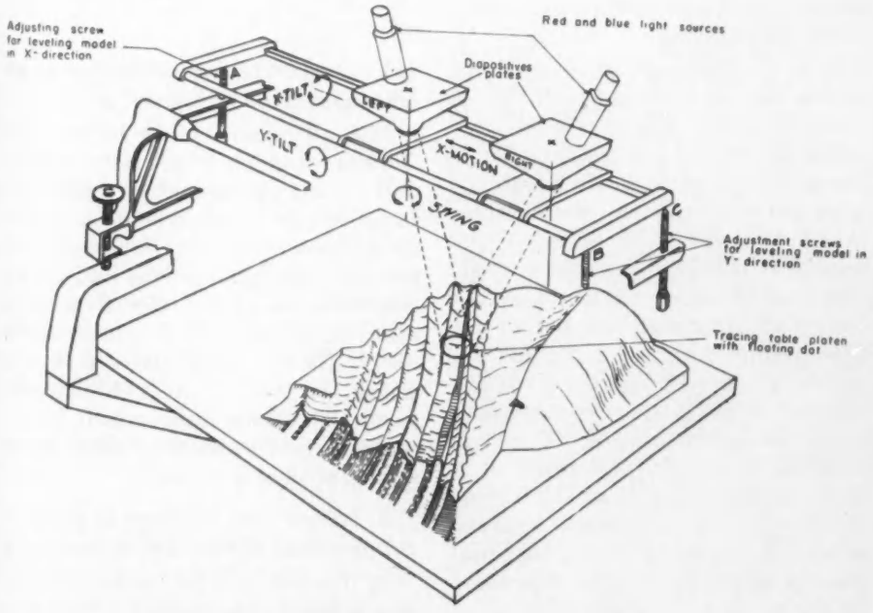

FIGURE 5—Schematic diagram of anaglyph-type plotters.

struments, ground control is necessary for proper orientation of the terrain model. In the case of the Stereotope and diapositive instruments, a minimum of four control points per model located at the corners of the model are necessary, and an extra control point in the approximate center of the model is advisable. For quantitative photogeologic work, this ground control may be obtained in a number of ways:

- When air photos being used for the photogeologic work have also been used for accurate topographic map construction, it is often possible to obtain the original control points from the government agency or commercial firm which made the topographic maps. If the ground control points are not obtainable by this method, the necessary control points can be interpolated from the topographic maps.

- From ground surveys by plane table traverse or triangulation.

- Utilization of existing elevation information such as that required for geophysical work. It is necessary that these elevation points be precisely located on the air photographs and that they are obtainable in the required portions of the stereoscopic model.

- Use of precise first-order plotters as well as the multiple projector anaglyph plotters to bridge between more widely scattered surveyed points and to restitute the necessary control for the plotter being used in the quantitative photogeologic work. In this system a minimum of surveyed control is used and, in some cases, small-scale photographs can be used in the first order plotters to establish the necessary ground control. This results in considerable saving of time and cost over full ground surveys.

Geologic data obtained through quantitative photogeology are used in preparation of structural contour maps, profiles, isopach maps, and in hydrodynamic studies.

Preparation of structural contour maps is the most important phase. Procedure is similar to plane table mapping in that a stratigraphic section is built up; datum beds are selected; intervals are established and spot elevations are determined. The advantages of doing this type of work with a photogrammetric plotter over the conventional plane table method are:

- The operation is unaffected by inclement weather, difficulty of access to the area and limits of field operation within daylight hours.

- If ground control can be obtained without the necessity of having a survey party traverse the area, the work can be done on a confidential basis, unaffected by permits and risk of exposure.

- The cost is lower than obtaining the same information by ground surveys alone.

The selection of photography for structural contouring is important. The accuracy of the plotters is a direct function of the height of the camera above ground and not, as is commonly supposed, a function of the photographic scale. For instance a scale of 1/20,000 can be obtained with a camera having a lens of 6-inch focal length with a flight altitude of 10,000 feet and also with a camera having an 8¼-inch focal length lens with a flight altitude of approximately 13,750 feet. Although the scale is 1/20,000 in each case, the 6-inch photography is flown at a lower flight altitude and therefore provides more accurate spot elevations. Using an average spot elevation accuracy of 1/5,000 of the flight height, the 6-inch photography at 1/20,000 will provide a two foot elevation accuracy; whereas the 8¼-inch photography at the same scale will only provide a spot elevation accuracy of 2.75 feet. These figures represent ideal conditions. In actual practice, a somewhat greater error should be expected.

It is obvious that more accurate results can be obtained with lower flying heights. When new photography is planned for quantitative photogeologic work or when a choice is available of existing photography taken at several different flight heights, it is best to use that photography which will fit the minimum accuracy requirements, but not to use photography which will provide accuracy in excess of that required. For instance, if a structural contour map at a contour interval of 100 feet is required, photographs taken at a flight height of 25,000 or 30,000 feet would supply the necessary accuracy of spot elevations. The cost of aerial photography is generally dependent on the number of exposures required to cover a given area. If the focal length of the lens is decreased as the flight height is decreased, it is possible to preserve a constant scale and therefore the number of exposures remain constant.

As pointed out, a scale of 1/20,000 is provided by an 8¼-inch lens at 13,750 feet and also by a 6-inch lens at 10,000 feet. The same scale could be maintained with a 3-inch lens at 5000 feet. The photo scale and number of exposures are the same in all three cases, but the elevation accuracy would be greatest for the lower altitude photography with the 3-inch lens. It would appear most logical, therefore, to use extremely short focal length lenses at low altitudes to achieve the desired results. This is not followed for a number of photogrammetric and optical reasons. For practical purposes the anaglyph plotters are limited to either 6-inch or 8¼-inch lenses.

Therefore, with the lens focal length remaining the same, lower altitude photography requires more exposures to cover a given area than the higher altitude photography and is more expensive. Approximately twice as many photographs are required to cover the same area at a flight height of 7,500 feet versus a flight height of 10,000 feet when using a camera with a 6-inch lens.

In addition to the added initial cost of low altitude photography, an additional expense is incurred in that many more ground control points are required for any given area.

Photogrammetric structural contouring is applied in two different manners:

1. Quantitative refinement of anomalies already known

The anomalies may be known from previous work such as published data, field, photogeologic reconnaissance or submittals. Where an anomaly is known to exist, but structural contours are lacking, it is safe to assume that the average dip of the beds over the structure is in excess of 1° or 2°. This type of structure can usually be worked on high altitude, small-scale photography which, as described, will result in a considerable saving of time and cost.

2. Larger area coverage in geological provinces of very low regional dip

In this instance, the method is used as a primary exploration technique to detect low-order reversals and to pro-

vide quantitative data on them. Examples of areas where this method can be satisfactorily used are the low-dip portions of Kansas and Oklahoma, the Edwards Plateau of Texas, the Tertiary portions of the Intermontane Basins of the Rocky Mountains, the low-dip areas of Libya and the Parana Basin of Brazil.

This type of anomaly usually cannot be consistently detected by qualitative photogeology alone. The visual acuity in normal stereoscopic observation is insufficient to consistently observe very low regional dips and deviations from the regional dip. Therefore, accurate elevation control is needed since closures in the magnitude of 10 to 25 feet may be very important. Photographs taken at a flight altitude of 10,000 feet with a camera equipped with a 6-inch focal length lens (providing a scale of 1/20,000) are suitable for this phase. Figure 6 illustrates a structural contour map of this type superimposed on a contact print.

In some areas discontinuity of outcrops and the lack of identifiable key beds renders a complete structural contour operation unfeasible. Some quantitative data may be obtained by photogrammetric methods in these areas by a number of dip and strike measurements from which form lines may be drawn. There are two methods to obtain dip and strike measurements on the anaglyph projection plotter. One is the conventional three point method commonly used in plane table mapping where three elevation points are obtained on the same bed. These points are ideally located in an equilateral triangular pattern. The other method is by direct reading of the dip and strike by means of a tilting platen which is placed on the conventional platen of the tracing table (Figure 7). This device enables the operator to align the platen so that it coincides with the inclination of exposed beds. The degree of dip can be measured and is transferred, along with the strike and exact location of the outcrop, to the map compilation sheet.

Preparation of Profiles. Another important use of a precise plotting instrument in geology is the construction of profiles. Profiles form a basis for geological cross-sections utilizing the surface information alone or in conjunction with subsurface informa-

Photo courtesy Jack Ammann Photogrammetric Engineers, Incorporated

FIGURE 6—This area, in West Texas, covers about 9 square miles and is included on a single contact print. The elevations were determined on a Kelsh plotter and the structural contours are on a 10-foot interval. Production of this type map by conventional surface methods would require a minimum of 8 man-days. For rough terrain with difficult access, up to 14 man-days may be required. The same work can be done photogrammetrically in 2 man-days.

FIGURE 7—Tilting platen for direct dip readings.

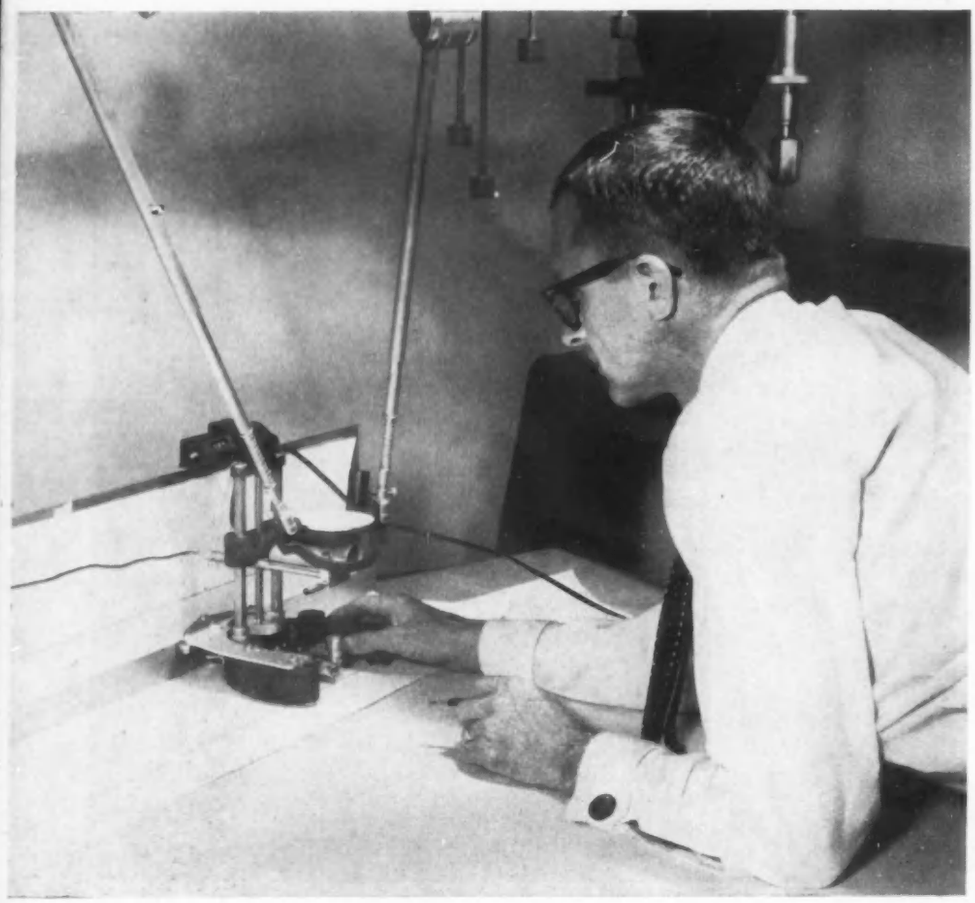

FIGURE 8—Profile plotting attachment installed on standard tracing table. The pencil traces a topographic profile as the tracing table traverses a straight line and is moved up or down to keep the floating dot in register with the ground surface. Surface geologic data incorporated into the profile can be used for a geological cross-section interpretation.

tion afforded by tests drilled within the area.

There are two methods of plotting profiles. The simplest is a modification of the tracing table which was designed by David Landen of the U. S. Geological Survey (Figure 8). The tracing table is mounted on a straight track which is oriented according to the profile direction. A pencil is mounted so that it projects from the movable platen in a horizontal direction. The profile is plotted by pencil on a strip of paper mounted on a board, aligned with the track.

As the tracing table is moved along the track, the floating mark is adjusted so that it is kept in continuous contact with the ground surface of the model. The pencil projecting from the platen, therefore, traces a profile of the topography onto the strip of paper. Upon completion of the topographic profile, surface positions of pertinent geologic features as formational contacts, key beds, lithologic units, fault traces and structural axes are added.

Dips and strikes are also established along the profile line by one of the two methods previously described. The other method of profile plotting is by means of an electrocoordinatograph which has also been described. Fine elevation accuracy is not as important in profile plotting as it is in structural contouring. Profiling can usually be done with a minimum of ground control; for reconnaissance profile work, it is possible to orientate the model according to drainage patterns without any known ground control. However, it is still necessary to derive an approximate horizontal scale of the model. The vertical scale of the profile is always the same as the horizontal scale; this is essential in calculating thicknesses and projecting surface geologic data into the subsurface.

Preparation of Isopach Maps. Isopach maps of an exposed sequence of rocks may be prepared using thickness data obtained photogrammetrically. If the rock sequence under consideration crops out in a restricted horizontal distance and is generally contained in single models, the technique of measuring the thickness is simple. Orientation of the model can be used as described for profiling, and the profile method can also be used for measuring the interval. It is not essential to carry a series of elevations for an isopach map, but only to establish intervals in a number of localities. The isopach data derived from the surface interval measurements can be tied into isopach data from the subsurface control.

Hydrodynamic Studies. For hydrodynamic studies in basins where the potential productive horizons crop out around the basin rim, it is necessary to plot the out-crop belt and determine a series of elevations on these horizons. Photogrammetric procedures can be used for this work. The profile technique is valuable in projecting the potential horizons from their out-crop positions into the subsurface.

ACKNOWLEDGMENT

The authors appreciate the helpful suggestions offered by Dr. Don B. Gould of Geophoto and Paul Blake of the U. S. Geological Survey, Topographic Branch, Denver.

About the Authors

Brundall

Jackson

Laurence Brundall studied geology at the University of Melbourne, Australia, and the University of Chicago where he received a degree in 1935. He is a member of the American Association of Petroleum Geologists, Fellow of the Geological Society of America, past director of the American Society of Photogrammetry and immediate past president of the Rocky Mountain Association of Geologists.

Vernon Jackson, supervisor of photogrammetric operations for Geophoto, studied geology at the Colorado School of Mines where he received a degree in 1951. Prior to his association with Geophoto in 1953, he was employed by Fairchild Aerial Surveys and the U. S. Geological Survey as a photogrammetric engineer. In addition to his work in photogeology, he has designed photogrammetric and photointerpretation instruments.

Why Blowouts Are Getting Few And Far Between

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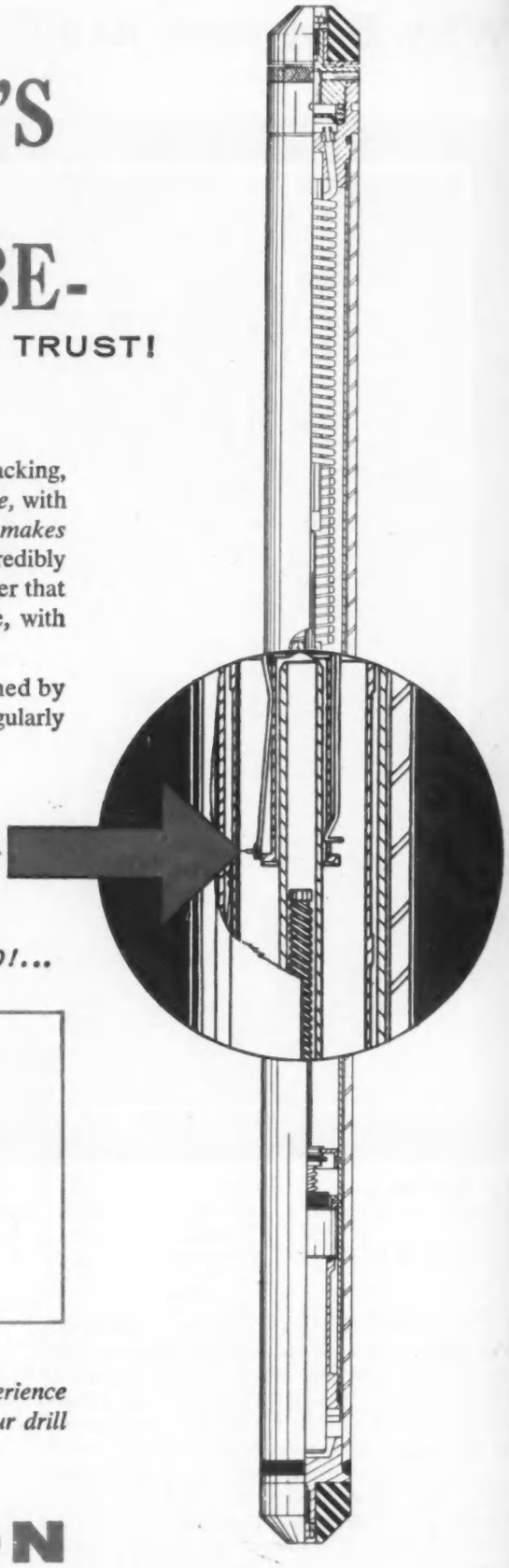

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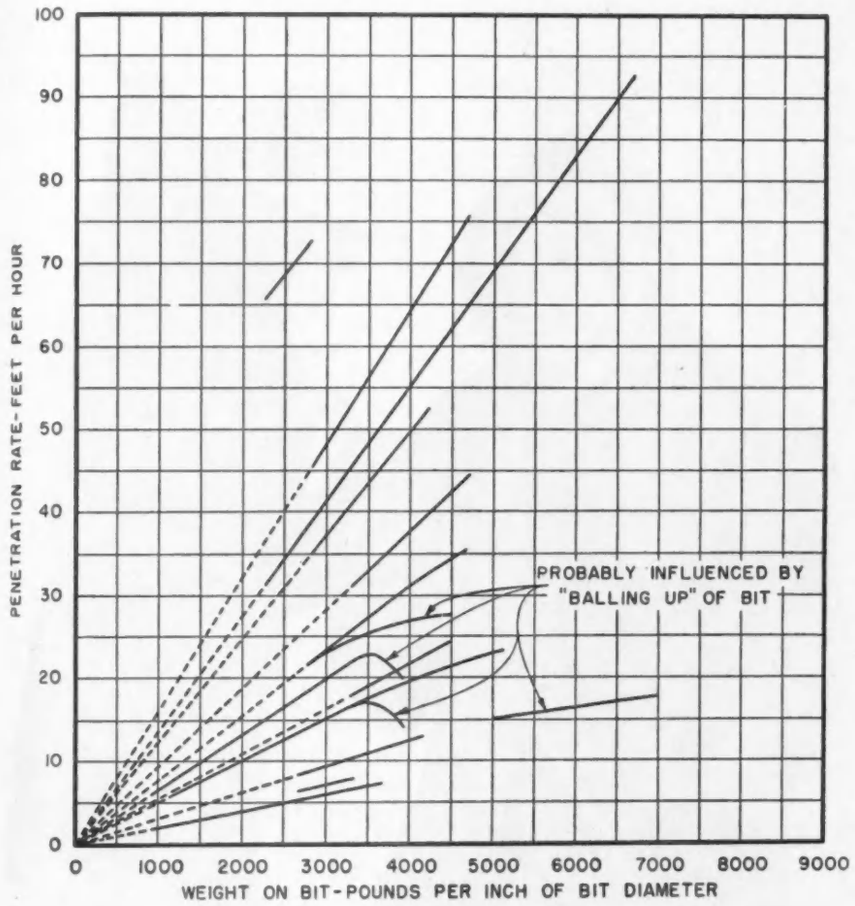

FIGURE 1—Relationship between rate of penetration and weight per inch of bit diameter-field results.

Here's a graphic method for . . .

Determining Optimum Drilling Techniques

Three parameters, their relationship to one another established in the laboratory and field, have been combined in one chart to speed selection of optimum weight and speed and proper hydraulics.

By John W. Speer, Shell Oil Company
New Orleans, La.

A SIMPLE graphical method for determining the combination of weight-on-bit, rotary speed, and hydraulic horsepower which produces minimum drilling cost has been developed. In the complete report, of which this is but an excerpt, empirical relationships were developed to show the influence on penetration rate of weight-on-bit, rotary speed and hydraulic horsepower. Optimum weight-on-bit is shown in relation to formation drillability, and optimum rotary speed is related to weight-on-bit. These five relationships are then combined into a chart for determining optimum drilling techniques from a minimum of field test data.

Because of space limitations and so as not to redevelop points that have been developed in other papers and talks this presentation is based on assumptions and conclusions that have been developed fully and were presented in detail in the original paper. namely:

1. Penetration rates of rock bits vary approximately in direct proportion with weight-on-bit in formations normally penetrated in oil field drilling, if sufficient circulating medium is provided to maintain clean bottom-hole conditions. The relationships for the formations encountered could therefore be approximately represented by a family of straight lines emanating from the origin of the graph (Figure 1).

2. Optimum weight-on-bit, or the weight which results in minimum footage cost, varies inversely with formation drillability. Therefore, an approximate relationship between optimum weight-on-bit and penetration rate can be developed. In Figure 2 the relationship between penetration rate and weight-on-bit are represented by a family of straight lines emanating from the origin of the graph, and a curve which is intended to represent optimum weight as a function of formation drillability. This latter curve was constructed as follows:

a. Field test results and general field practices indicate that optimum weight decreases as formations become softer (drillability increases).

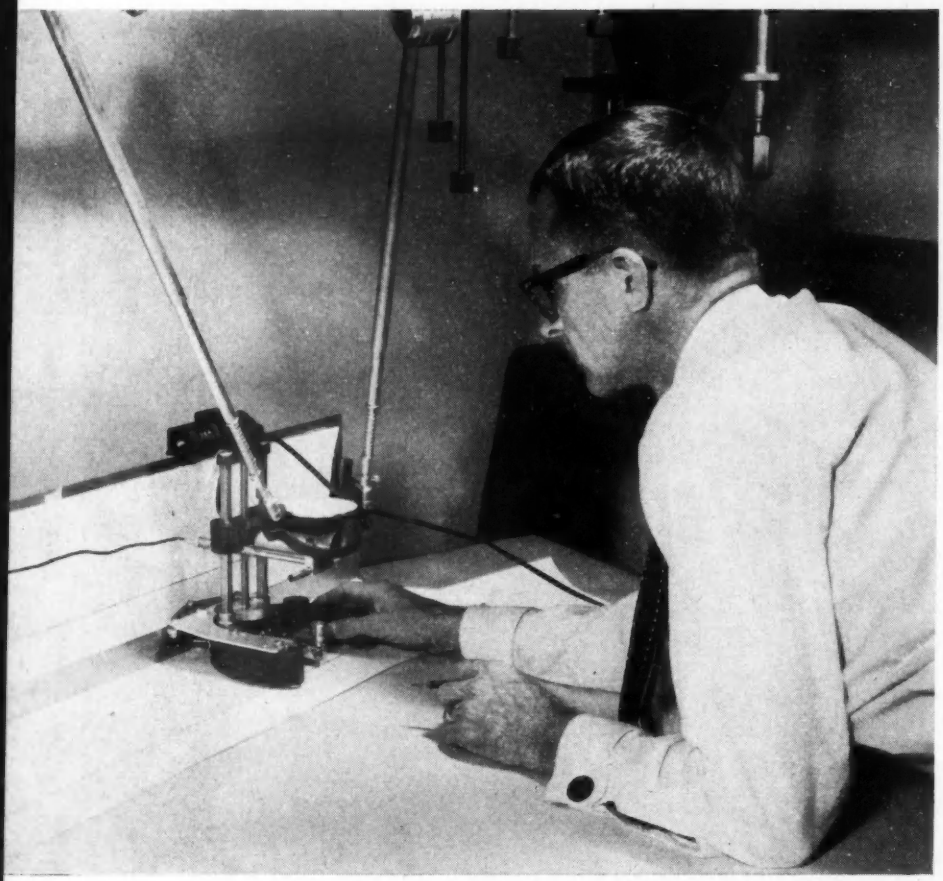

FIGURE 8—Profile plotting attachment installed on standard tracing table. The pencil traces a topographic profile as the tracing table traverses a straight line and is moved up or down to keep the floating dot in register with the ground surface. Surface geologic data incorporated into the profile can be used for a geological cross-section interpretation.

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There are two methods of plotting profiles. The simplest is a modification of the tracing table which was designed by David Landen of the U. S. Geological Survey (Figure 8). The tracing table is mounted on a straight track which is oriented according to the profile direction. A pencil is mounted so that it projects from the movable platen in a horizontal direction. The profile is plotted by pencil on a strip of paper mounted on a board, aligned with the track.

As the tracing table is moved along the track, the floating mark is adjusted so that it is kept in continuous contact with the ground surface of the model. The pencil projecting from the platen, therefore, traces a profile of the topography onto the strip of paper. Upon completion of the topographic profile, surface positions of pertinent geologic features as formational contacts, key beds, lithologic units, fault traces and structural axes are added.

Dips and strikes are also established along the profile line by one of the two methods previously described. The other method of profile plotting is by means of an electrocoordinatograph which has also been described. Fine elevation accuracy is not as important in profile plotting as it is in structural contouring. Profiling can usually be done with a minimum of ground control; for reconnaissance profile work, it is possible to orientate the model according to drainage patterns without any known ground control. However, it is still necessary to derive an approximate horizontal scale of the model. The vertical scale of the profile is always the same as the horizontal scale; this is essential in calculating thicknesses and projecting surface geologic data into the subsurface.

Preparation of Isopach Maps. Isopach maps of an exposed sequence of rocks may be prepared using thickness data obtained photogrammetrically. If the rock sequence under consideration crops out in a restricted horizontal distance and is generally contained in single models, the technique of measuring the thickness is simple. Orientation of the model can be used as described for profiling, and the profile method can also be used for measuring the interval. It is not essential to carry a series of elevations for an isopach map, but only to establish intervals in a number of localities. The isopach data derived from the surface interval measurements can be tied into isopach data from the subsurface control.

Hydrodynamic Studies. For hydrodynamic studies in basins where the potential productive horizons crop out around the basin rim, it is necessary to plot the out-crop belt and determine a series of elevations on these horizons. Photogrammetric procedures can be used for this work. The profile technique is valuable in projecting the potential horizons from their out-crop positions into the subsurface.

ACKNOWLEDGMENT

The authors appreciate the helpful suggestions offered by Dr. Don B. Gould of Geophoto and Paul Blake of the U. S. Geological Survey, Topographic Branch, Denver.

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Brundall

Jackson

Laurence Brundall studied geology at the University of Melbourne, Australia, and the University of Chicago where he received a degree in 1935. He is a member of the American Association of Petroleum Geologists, Fellow of the Geological Society of America, past director of the American Society of Photogrammetry and immediate past president of the Rocky Mountain Association of Geologists.

Vernon Jackson, supervisor of photogrammetric operations for Geophoto, studied geology at the Colorado School of Mines where he received a degree in 1951. Prior to his association with Geophoto in 1953, he was employed by Fairchild Aerial Surveys and the U. S. Geological Survey as a photogrammetric engineer. In addition to his work in photogeology, he has designed photogrammetric and photointerpretation instruments.

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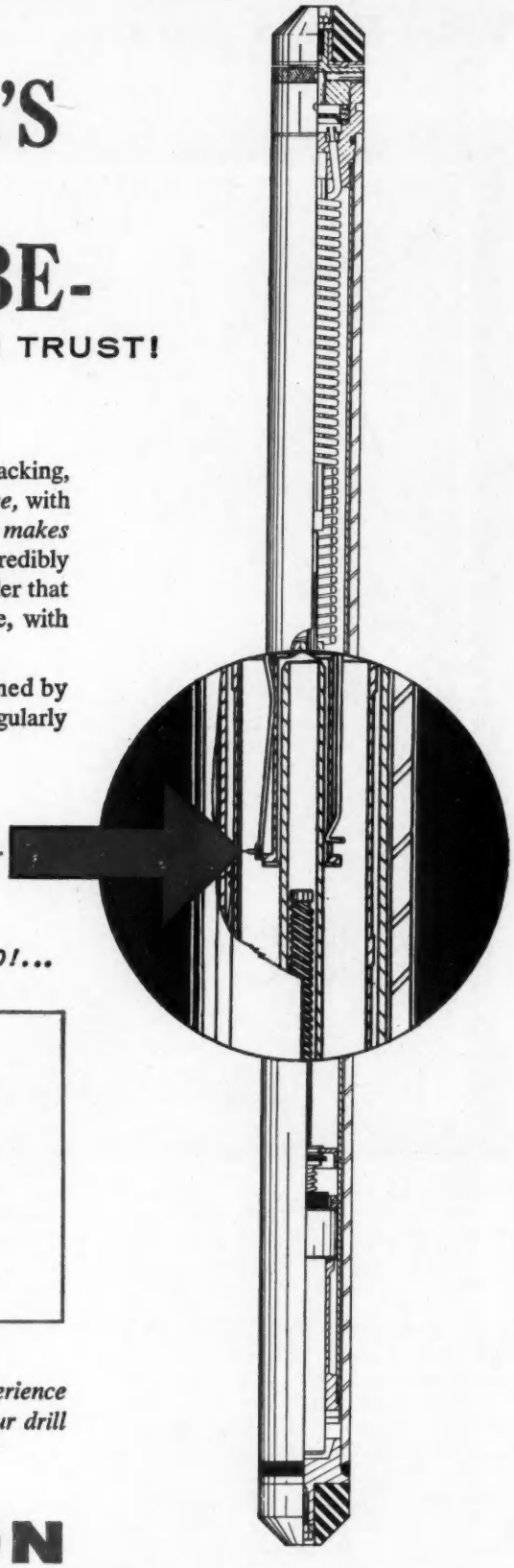

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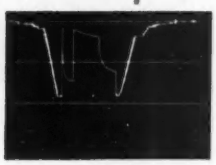

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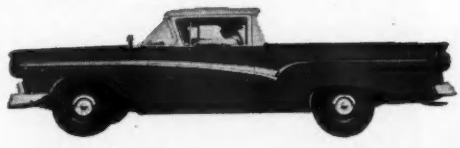

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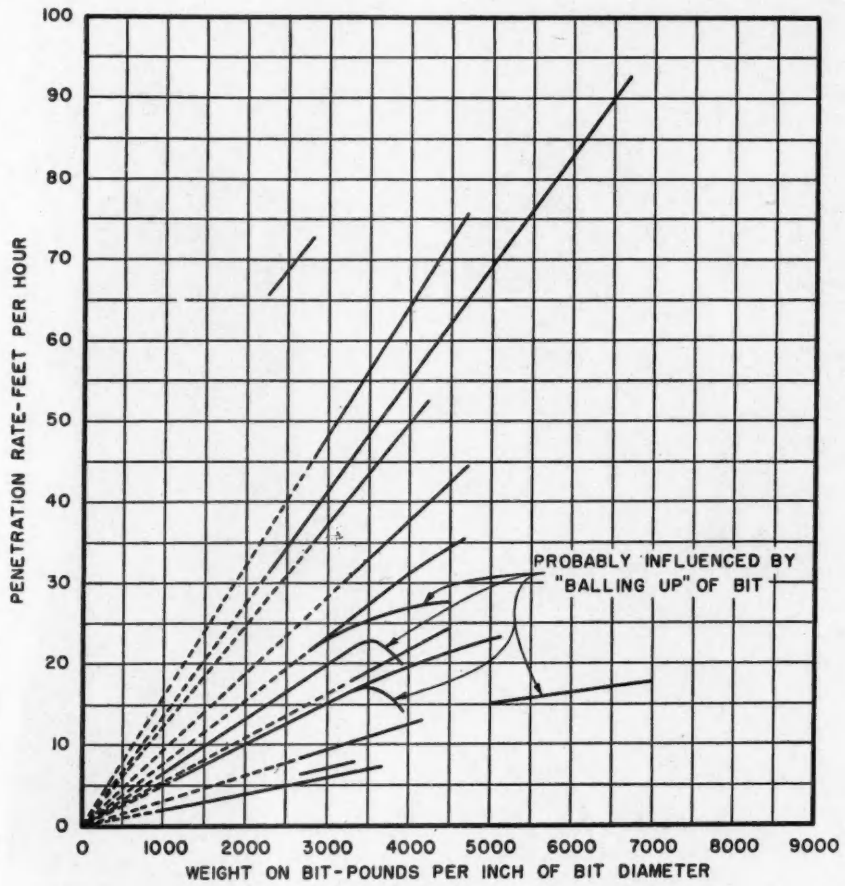

FIGURE 1—Relationship between rate of penetration and weight per inch of bit diameter-field results.

Here's a graphic method for . . .

Determining Optimum Drilling Techniques

Three parameters, their relationship to one another established in the laboratory and field, have been combined in one chart to speed selection of optimum weight and speed and proper hydraulics.

By John W. Speer, Shell Oil Company
New Orleans, La.

A SIMPLE graphical method for determining the combination of weight-on-bit, rotary speed, and hydraulic horsepower which produces minimum drilling cost has been developed. In the complete report, of which this is but an excerpt, empirical relationships were developed to show the influence on penetration rate of weight-on-bit, rotary speed and hydraulic horsepower. Optimum weight-on-bit is shown in relation to formation drillability, and optimum rotary speed is related to weight-on-bit. These five relationships are then combined into a chart for determining optimum drilling techniques from a minimum of field test data.

Because of space limitations and so as not to redevelop points that have been developed in other papers and talks this presentation is based on assumptions and conclusions that have been developed fully and were presented in detail in the original paper, namely:

1. Penetration rates of rock bits vary approximately in direct proportion with weight-on-bit in formations normally penetrated in oil field drilling, if sufficient circulating medium is provided to maintain clean bottom-hole conditions. The relationships for the formations encountered could therefore be approximately represented by a family of straight lines emanating from the origin of the graph (Figure 1).

2. Optimum weight-on-bit, or the weight which results in minimum footage cost, varies inversely with formation drillability. Therefore, an approximate relationship between optimum weight-on-bit and penetration rate can be developed. In Figure 2 the relationship between penetration rate and weight-on-bit are represented by a family of straight lines emanating from the origin of the graph, and a curve which is intended to represent optimum weight as a function of formation drillability. This latter curve was constructed as follows:

a. Field test results and general field practices indicate that optimum weight decreases as formations become softer (drillability increases).

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FIGURE 2—Weight-on-bit for most economical cost versus formation drillability. $\left(\text{Drillability} \propto \frac{\text{penetration rate}}{\text{weight}}\right)$ All curves predicated on basis sufficient hydraulic horsepower available to insure clean bottom-hole conditions.

Therefore, the general direction of the curve is known.

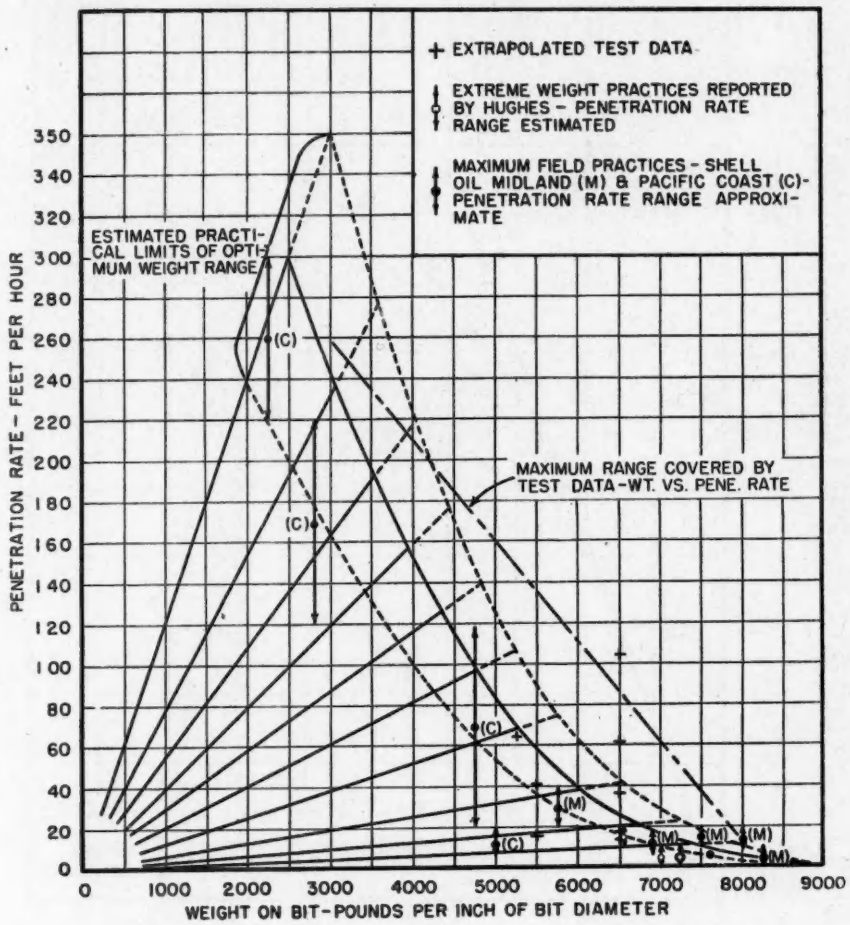
b. The placement of the curve on the graph was estimated from the field test results (extrapolated), general field practices from Pacific Coast and Permian Basin, and extreme weight practices for various areas as reported by Hughes.[1] Recognizing the inaccuracy which could be incurred in extrapolating field test results, they were not weighted heavily in construction of the curve. General field practices (reported by Hughes) are usually found to be slightly lower than optimum weight because several field problems, such as hole deviation, restrict weight for reasons other than bit life; there ore, the curve was made to pass slightly above these points. Likewise, Pacific Coast practices are known to be slightly lower than optimum because of deviation problems, and these values were treated similarly. Permian Basin practices are relatively free of interference from other problems, and weight practices are governed primarily by footage cost; therefore, the curve was made to pass through these points.

In addition, a range of weights within which near-minimum footage cost should result, was incorporated in the graph because field test results indicate that within a range of 2000 ± PIBD encompassing optimum weight, costs do not vary appreciably, and because it is recognized that a finite optimum weight curve cannot be constructed with the information available.

3. Penetration rate of a rock bit under laboratory test conditions varies in direct proportion with speed of rotation.

4. Penetration rate of a rock bit under field operation conditions varies in a decreasing function with rate of rotation; i.e., the response of penetration rate to increases in rotary speed decreases as rotary speed is increased.

5. It appears that optimum rotary speed, or the rotary speed which results in minimum cost, varies inversely with weight-on-bit, and an approximate relationship between weight-on-


+ EXTRAPOLATED TEST DATA
EXTREME WEIGHT PRACTICES REPORTED BY HUGHES – PENETRATION RATE RANGE ESTIMATED
MAXIMUM FIELD PRACTICES – SHELL OIL MIDLAND (M) & PACIFIC COAST (C) – PENETRATION RATE RANGE APPROXIMATE
ESTIMATED PRACTICAL LIMITS OF OPTIMUM WEIGHT RANGE
MAXIMUM RANGE COVERED BY TEST DATA – WT. VS. PENE. RATE
PENETRATION RATE – FEET PER HOUR
WEIGHT ON BIT – POUNDS PER INCH OF BIT DIAMETER

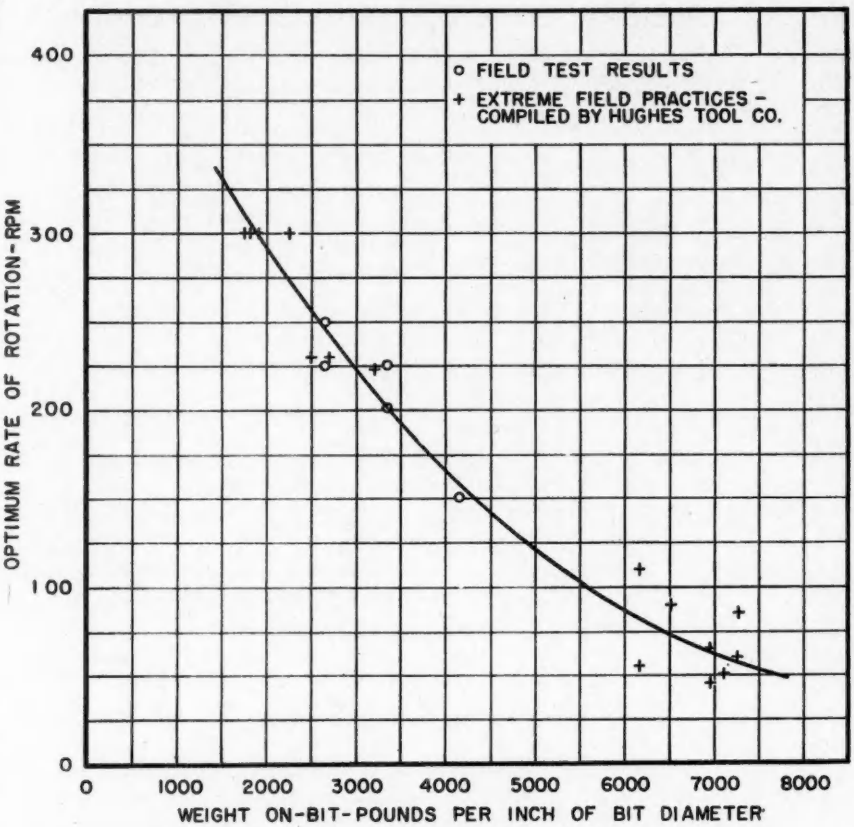

o FIELD TEST RESULTS
+ EXTREME FIELD PRACTICES – COMPILED BY HUGHES TOOL CO.
OPTIMUM RATE OF ROTATION – RPM
WEIGHT ON-BIT-POUNDS PER INCH OF BIT DIAMETER

FIGURE 3—Optimum rate of rotation as a function of weight on bit.

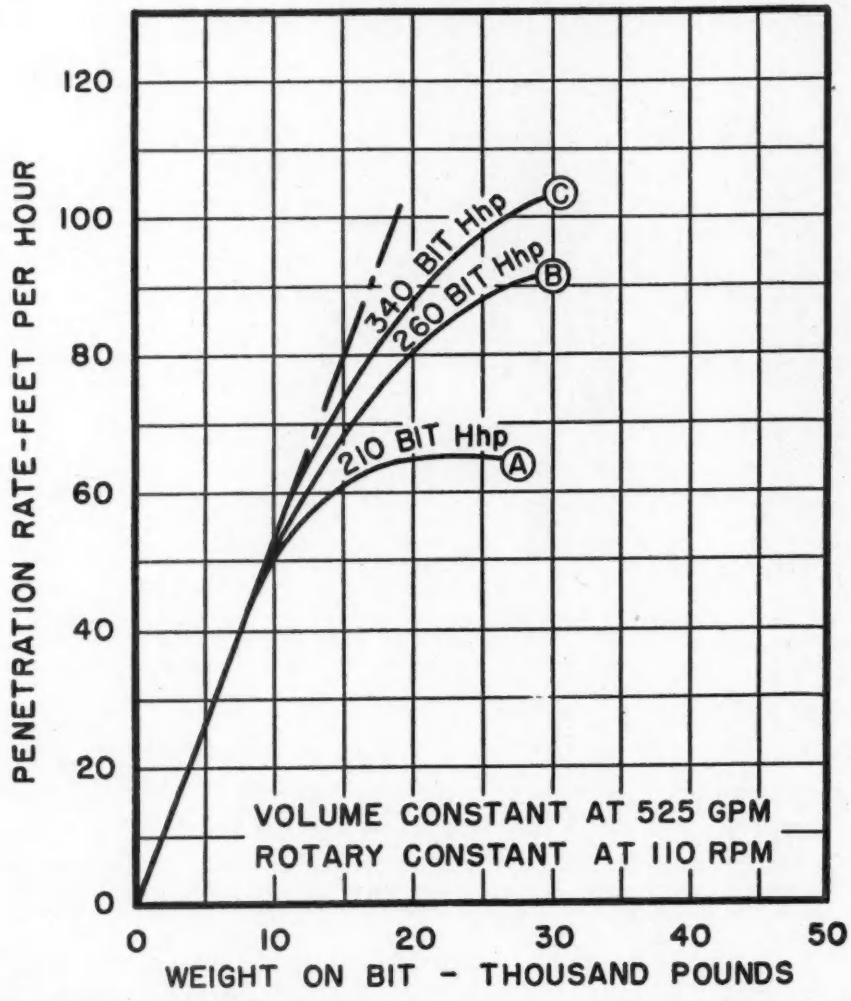


FIGURE 4—Influence of lack of hydraulic horsepower or "balling up" on penetration rate. (Taken from Reference 6.)

bit and optimum rotary speed can be developed. (Figure 3)

6. Hydraulic horsepower required for optimum bottom-hole scavenging varies lineally with penetration rate in any specific formation which is demonstrated in Figure 4. Under certain circumstances an increase in hydraulic horsepower will produce an increase in penetration rate even when not accompanied by an increase in weight. Consider the condition of 20,000 pounds of weight and a penetration rate of 65 feet per hour. When hydraulic horsepower across the bit was increased from 210 to 260, penetration rate increased to 80 feet per hour, even without an increase in weight, because the additional hydraulic horsepower reduced balling up. Likewise, further increase in hydraulic horsepower to 340 produced an additional increase in penetration rate because the balling up condition was further reduced. (Figure 4)

7. The advantage in drilling efficiency of the jet bit over the regular bit is a minimum in medium hard formations, and increases directly with softness of formations.

8. Minimum nozzle fluid velocity for effective jet bit application varies from 170 ± feet per second in soft formations to 225 ± feet per second in medium hard formations.

9. The three-cone regular bit performs better than the cross-section regular bit.

A Method For Determining Optimum Drilling Techniques. By combining the relationships between (1) penetration rate and hydraulic horsepower, (2) penetration rate and weight-on-bit, (3) optimum weight-on-bit and penetration rate, and (4) optimum rotary speed and weight-on-bit, a method for predicting approximate optimum drilling techniques can be developed.

Determining optimum drilling techniques includes determining the combination of weight-on-bit, rotary speed, and hydraulic horsepower which results in minimum drilling cost for a certain formation. The use of jet bits is presumed, as their performance is not worse than a conventional bit, although sometimes not much better. General rules for selection of bit tooth type cannot be given because of the major influence of formation, and it is presumed that on-the-spot selection is adequate. Type of circulating fluid is not included for the same reason.

In practice, the determination of optimum drilling techniques actually consists of three problems: (1) to determine the best weight and rotary speed practices for the equipment in use; (2) to determine the equipment (pump), and weight and rotary speed practices required to achieve minimum footage cost, and (3) determine best weight and rotary speed practices for any intermediate equipment. It appears that these three problems can be solved reasonably well with a very small amount of field testing, by combining the several relationships which have been developed here, as in Figure 5.

Figure 5 consists of a chart comprised of the relationship between (1) penetration rate and weight-on-bit, (2) penetration rate and hydraulic horsepower and (3) penetration rate and optimum weight-on-bit, and (4) the relationship between optimum rotary speed and weight-on-bit. The component parts of this chart were derived and plotted from both laboratory and field test data and are fully explained in the original paper. (See acknowledgment.) The function of the chart can best be explained with a simplified example.

Assume that a certain rig is available to drill a 1000-foot homogeneous shale section, and it is desirable to determine optimum techniques with the available rig, and the equipment required to most economically drill the shale section. The initial conditions are as follows:

1. 400 hydraulic horsepower pump.
2. 4½-inch drill pipe.
3. 9⅞-inch hole.
4. 3 x ½-inch bit nozzles.

When the shale section is drilled, short-duration tests of weight versus

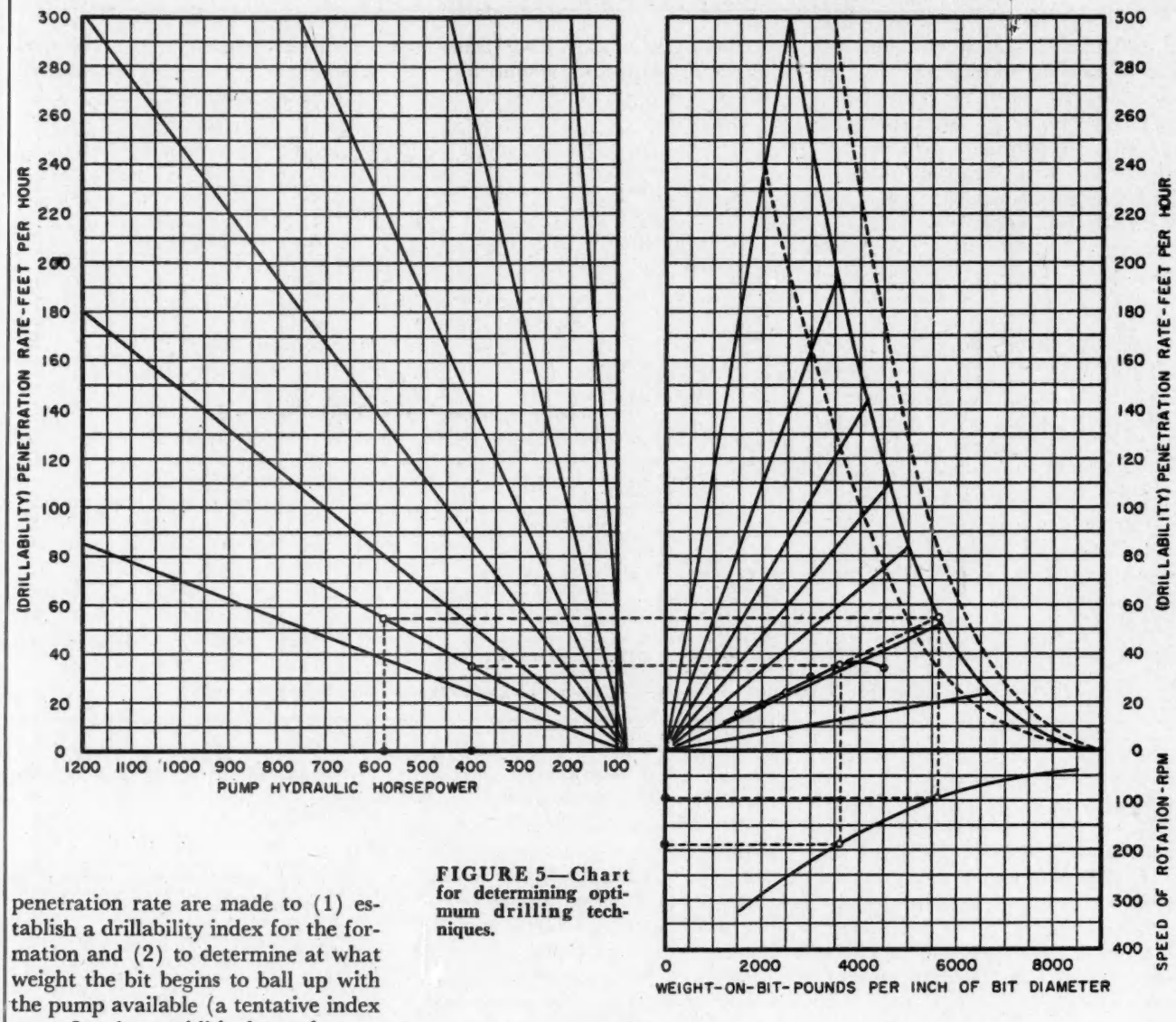


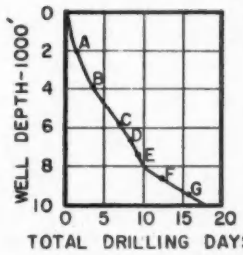
FIGURE 5—Chart for determining optimum drilling techniques.

penetration rate are made to (1) establish a drillability index for the formation and (2) to determine at what weight the bit begins to ball up with the pump available (a tentative index must first be established to select an appropriate rotary speed). These test values are plotted on the weight versus penetration rate chart (upper right hand section) and an appropriate curve drawn through them. The low-weight section of this curve should be linear until the bit begins to ball up. From the point on this curve where the bit begins to ball up, a horizontal line is drawn left to intersection with 400 hydraulic horsepower. This single point is sufficient to draw the linear relationship between hydraulic horsepower and penetration rate for this shale section. It will be noticed that this index is in a sense dimensionless, inasmuch as it includes hole size, type of bit, drill pipe size, etc. Also from the weight where the bit begins to ball up, a vertical line is drawn downward to intersect with the optimum rate of revolution curve. Thus, from these manipulations, this formation would be most economically drilled with a weight of 3600 pounds per inch of bit diameter (35,000 pounds) and 190 rpm rotary speed, with the 400 hydraulic horsepower pump available.

Now return to the weight versus penetration rate index and extend the linear section of the curve to intersect the optimum weight-on-bit curve. From this point a horizontal line is drawn left to intersect the hydraulic horsepower index curve already established for this formation. This intersection gives the hydraulic horsepower required to maintain sufficient bottom-hole cleaning to permit use of optimum weight. A vertical line is also drawn downward to determine optimum speed of rotation for the new weight. These manipulations show that minimum footage cost could be achieved in this formation with a 580 hydraulic horsepower pump, used in conjunction with a weight of 5600 pounds per inch of bit diameter (55,000 pounds) and 95 rpm. By working backwards from the hydraulic horsepower index curve, the best weight and rotary speed practices for any hydraulic horsepower can also be determined in the same way.

This was purposely made a simplified example including only a homogeneous shale section; to determine optimum drilling techniques for a field would involve more formations, usually two to four. Therefore, it would be necessary to make weight versus penetration rate tests in each of the principal formations penetrated and treat each formation separately as a problem. Obviously, instantaneous penetration rate will vary ap-

Problem: Determine optimum drilling techniques for available rig and rig equipped with 500 Hhp pump, and determine pump capacity required and optimum drilling techniques for new rig, that result in minimum cost. Available rig equipped with 400 Hhp pump.



Initial well drilled as follows:

1. 9⅞ inch hole
2. 4½ inch drill pipe
3. 400 hydraulic horse power pump
4. Jet bits—3 x ½ inch nozzles

Information desired:

1. Optimum weight and rotary speed practices for 400 Hhp pump (rig used for test).
2. Optimum weight and rotary speed practices for 500 Hhp pump (second rig to be moved into field).
3. Equipment and techniques required to achieve minimum cost.

Drilling progress curve for field (used to determine how many basic formations penetrated).

Test Information

TESTS	A	B	C	D	E	F	G
WEIGHTS	PENETRATION RATE—FT./HR.						
1000 PIBD	93	22	15	16	13	5	3
2000	188	45	25	35	23	8	5
3000	203	55	40	50	36	10	6
4000	...	40	40	55	47	15	8
5000	...	..	35	47	47	12	9
6000	...	..	..	..	..	..	6

Information From Chart, Figure 5

TESTS	A	B	C	D	E	F	G
OPT. TECH. 400 Hhp:							
WT.-PIBD	2000	2500	3000	3200	4000	4000	4500
RPM	290	255	225	210	165	165	140
OPT. TECH.-500 Hhp:							
WT.-PIBD	2600	3200	3950	4300	5200	5300	5700
RPM	250	210	170	150	110	105	90
OPT. TECH:							
Hhp*	525	700	650	575	525	600	600
WT.-PIBD	2800	4750	5300	5000	5400	6800	7200
RPM	235	130	105	120	100	70	55

* 650 Hhp PUMP SELECTED FOR NEW RIG

FIGURE 6—Example of function of Figure 5 in determining optimum drilling techniques for a field.

preciably over these large depth intervals; however, this does not effect use of the chart appreciably because it is impractical to vary weight rapidly and continuously while drilling and because the chart was constructed from the averaged field data. The primary precaution that must be taken is that the results from the field tests are representative of average penetration rates throughout the interval.

Figure 6 gives an example of the function of the chart for this purpose. Using whatever rig is available, several weight versus penetration rate tests are made in each of the three major formations penetrated in order to establish the appropriate indices (an appropriate rotary speed is estimated for each test series). Care must be exercised to ensure that the balling up weight is clearly demonstrated in each test. From the results of each of these tests, optimum techniques are predicted for the desired conditions (400 and 500 Hhp pumps, and optimum pump), as in the single example above. For the two conditions of known hydraulic horsepower, a work sheet giving weight and rotary speed practices to achieve minimum cost, can now be prepared.

For selecting the optimum pump size a compromise between the various optimum pump Hhp indicated must be made, placing emphasis on that section of the hole which will require most drilling time. For this example, 650 Hhp well covers maximum pump requirements except for one short interval, which can be ignored. After establishing the pump which is to be obtained, weight and rotary speed practices are re-evaluated and a work sheet prepared similar to the one mentioned above.

All of these techniques are related to the original conditions; 9⅞-inch hole, 4½-inch drill pipe, 3 x ½-inch nozzles. Transformation to different conditions requires some estimating. A change in size of drill string could be made by computing the hydraulic horsepower necessary to provide equal circulating rates and nozzle fluid velocities. (Assuming rising velocity adequate under both conditions). Transformation to various hole sizes would be less accurate, and probably should be made on the basis of hole diameters squared.

The above described procedure is intended only to assist in arriving at near-optimum drilling techniques in the shortest possible time. It is again pointed out that this chart is, as yet, very tentative, and it would be advisable in any case to continue field testing in order to refine drilling techniques.

ACKNOWLEDGMENT

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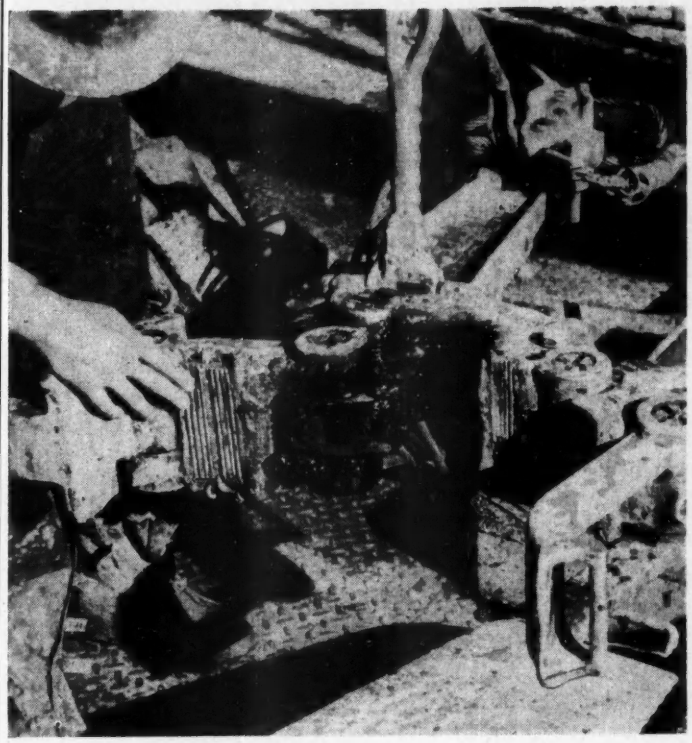

FIGURE 1—Checking the condition of the tongs and the tong dies before making a trip is safe work practice. Sharp dies are essential for proper operation of the tongs and reduce the possibility of the tongs slipping on the pipe and slamming into a crewman.

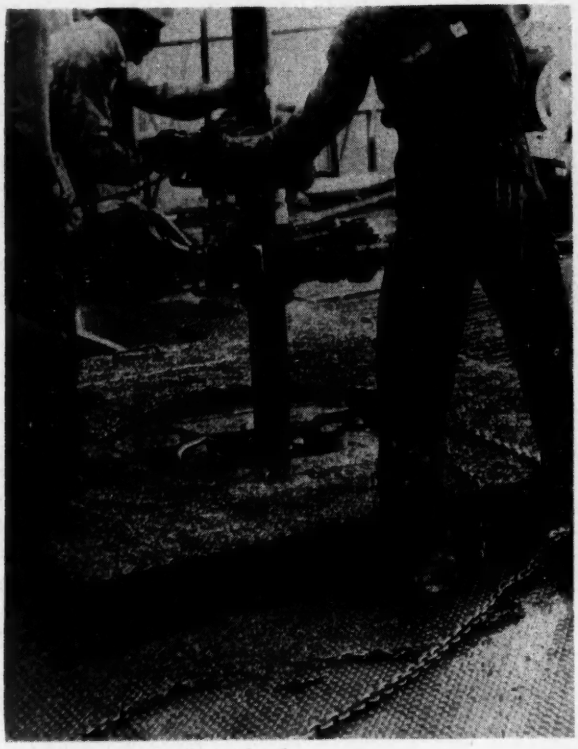

FIGURE 2—Example of a good rig floor with a non-skid surface on floor and rotary table. Floor and rotary table have been washed down and cottonseed hulls are being used to reduce slipping hazard when floor becomes wet.

Rig Accidents—Causes and Remedies

Equipment failures take their human toll, but at the base of most accidents is a human failure, forgetfulness, oversight, sloppy work, lack of caution, working too fast, etc. A little time checking on personal work habits may save your life.

A DRILLING RIG is an expensive, complex device for making a hole in the ground. But it can be a frightening instrument of pain, mutilation or death when the basic rules and common sense of safe working practices are ignored or forgotten.

There has been progress in the reduction of accidents on the rig. In 1951, the accident frequency was 44.00; last year it was 33.86. Nevertheless, accident rates on the drilling rig are still the highest in the industry —almost double the frequency of the second most hazardous oil activity. Drilling has the highest severity rate in the industry, according to API figures. This means the accidents are more serious, the deaths more numerous per man-hour.

Because of the nature of the work, the heavy equipment used, and the demands for extremely high efficiency, drilling crewmen have a greater responsibility for accident prevention than do most groups in the industry. The press of activity and the independent spirit of the crew member leads to a dangerous attitude toward his work—he tempts danger, he takes a chance.

This article discusses some of the most frequent types of rig accidents. These accidents almost always are caused by dangerous working practices which imperil the crewmen on the rig. The accidents discussed here are those brought about by flying, falling or swinging objects.

Consider the crescent wrench, for example, a valuable tool, indispensable to the rig crewman. Now consider the crescent wrench as it lies, unattached, on the monkey board. Kicked accidentally, it falls down the derrick, and at six feet above the derrick floor, it is travelling about 4000 feet per minute, 45 miles an hour. If it strikes a workman's safety helmet or shoulder, it slams into him with a force of about 8500 pounds; that's the combined weight of two heavy automobiles. With a safety hat on, he would be knocked senseless; without a safety hat . . . !

Accidents caused by dropping small tools from the derrick are fairly common on the drilling rig. If you're a rig crewman, you can probably remember many close calls as wrenches

or pliers buzzed by your head to crash on the derrick floor; and you'll remember looking up angrily at the man who dropped the tool to see him looking sheepish and apologetic. It's simple to avoid dropping small tools when working up in the derrick—it's necessary only to tie the hand tool to yourself with a piece of soft rope. Every crewman on the rig knows about this precaution, yet sometimes people forget, or tell themselves it's too much trouble.

Let's consider some other typical cases of accidents caused by falling, flying or swinging objects. The cases listed below actually happened. Some of them are shocking; but they are by no means unusual.

Case 1

This falling "object" was the crewman himself. He slipped on a wet rotary table, struck a slip handle, broke his leg.

Remedy: Use non-skid covering for wet surfaces. In addition, wash down and clean floor as frequently as practicable.

Case 2

Crewman was setting slips when the balance line on the tongs slipped, the tongs fell and smashed his hand. The damages: Fractured, mutilated hand.

Remedy: Before starting any job, check your equipment for proper functioning and safety. This holds for any equipment you normally use on the job, whether you prepared it for operation or it was prepared by others.

Case 3

The mud hose became plugged, causing the pump head to burst. Mud spewed over the crewman and blinded him momentarily. In his haste to avoid the spray, he fell, fracturing a leg, suffering a brain concussion and injuring his kidneys.

Remedy: This accident illustrates the need for continual rechecks of equipment for proper operation. The mud hose and relief valve were okay when the job started but became plugged later. The original check was fine, but failure to re-check caused a serious accident.

Case 4

The tong snapped while breaking out drill collars. A piece of steel struck the floorman in the stomach. He suffered severe lacerations, gross hemorrhage, and shock.

Remedy: Despite ordinary precautions, equipment failure can cause accidents. It is the driller's responsibility as well as the crewman's to make sure that old equipment which has had long use is checked frequently. Management endorses the program of replacing worn and old equipment, but the driller and the crewman must decide when the equipment should be retired.

Case 5

Crewman's arm became entangled in the spinning chain while making up a joint. He was slammed against the drill pipe. The driller cut power at once, but not soon enough. The man suffered a badly smashed hand and wrist.

Remedy: The only remedy here is for the crewman to think before he begins each individual phase of his work. Crewman here was familiar with his work, but had lost respect for the dangerous aspects of it.

Case 6

Crewman was making up a joint of drill pipe, and a tong slammed into his chest, knocking him to the rotary floor. He suffered severe bruises and lacerations.

Remedy: Check tong snubbing line and keep out of the arc of the tong handles.

Case 7

A stand of drill pipe dropped from the elevators onto a crewman's foot. Result: Amputation, profound shock. In this case, the elevators were so encrusted with mud they didn't latch properly.

Remedy: There were two mistakes obvious here. First, the equipment was allowed to get so dirty it would not operate properly. Second, the crewman's foot was under the falling pipe. Maintain equipment in good operating condition and keep feet clear of pipe at all times.

Case 8

A stabbing board was mounted in the derrick. Swinging elevators hit the board, knocked it to the derrick floor where it struck the unprotected head of a crewman, causing skull fracture and death. Crewman on the stabbing board was not hurt, because he was tied securely to the derrick by his safety belt.

Remedy: The importance of wearing the safety hat on the rig is demonstrated once more in this accident. No accurate estimate of the number of lives saved by the safety hat is possible; but it is certain that without the safety hat, death or serious injury is much more likely.

Case 9

Crewman was descending the derrick ladder when the wind blew off his safety hat. Crewman descending above him dropped a light wrench which struck the hatless man below. The injured man clung to the derrick, was rescued. He suffered a severe scalp wound.

Remedy: This accident points to two unsafe practices. First, the crewman should have fastened his safety hat to his head. Second, the crewman above him should have fastened the wrench to himself.

If you've ever experienced the sound of steel against flesh, the sight of mutilated wounds or the specter of splintered bone; if you've ever felt the violent shock of steel smashing into your body—you know the most intimate detail of accident. You'll remember the shocking sights and sounds. You'll remember the voices of the injured and the faces of their families.

To the safety man or rig foreman who studies accidents, such remembering is the spur to finding more and better ways to try to reduce accident rates. But the safety man is the least important factor in accident prevention—he can only "view with alarm," suggest, urge.

The people who must prevent rig accidents are rig personnel and drilling management, working together. If each man—drilling company president to rankest boll weevil—considers these simple rules and puts them in effect, accidents of all kinds on the rig will be dramatically reduced:

- Think before you act.
- Plan your work carefully.
- Check your equipment frequently.
- Remember that you're also responsible for the safety of your fellow crewmen.
- Keep in mind that accidents can happen to you. —**The End**

WHICH PUMP HAS THE LOWEST WEIGHT PER H. P.?

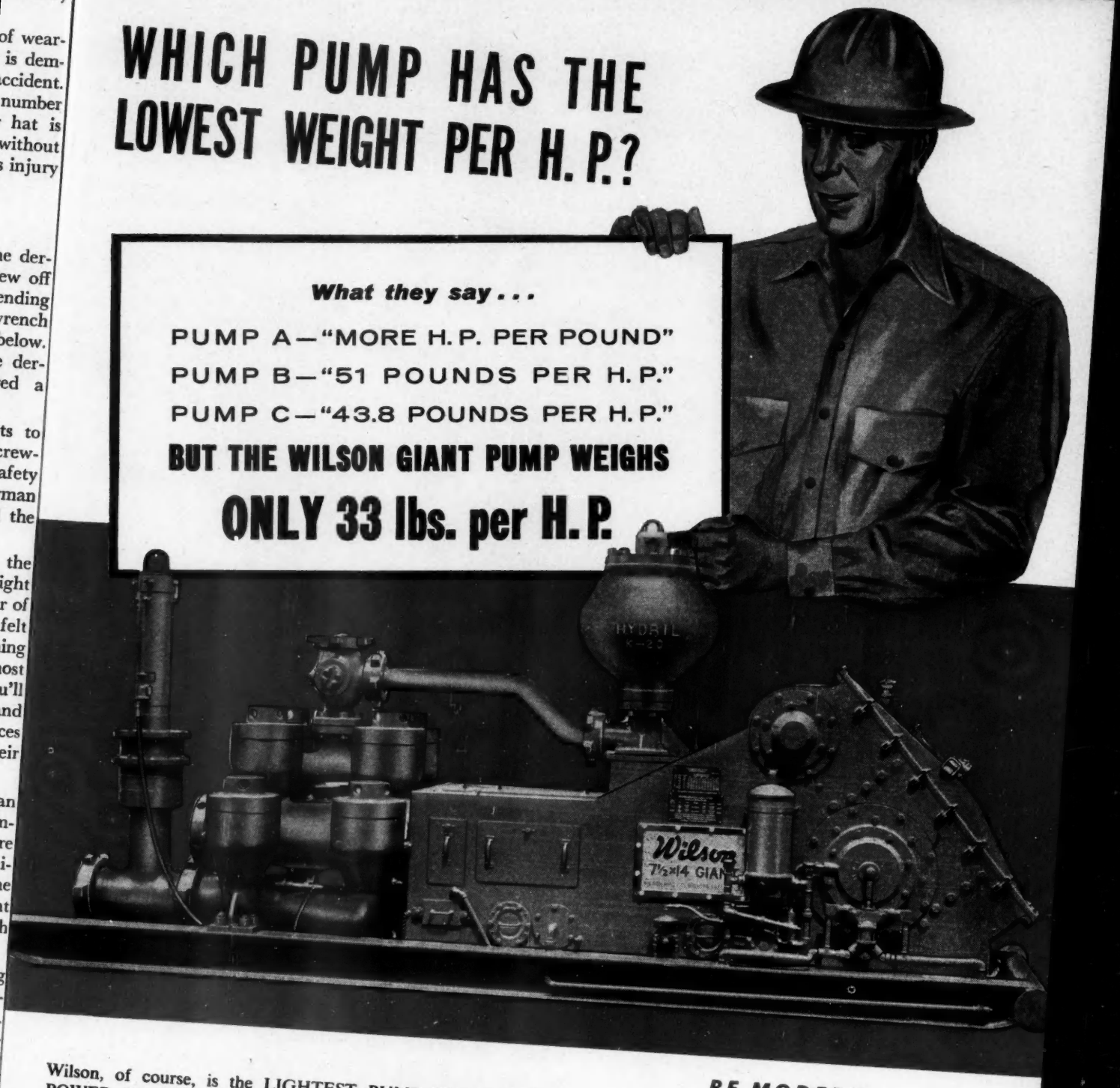

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FIGURE 1—Compactly mounted on the skid, behind the master clutch, the 24-inch coupling provides a "soft" drive to the drawworks.

"Run-Around" Provides "Soft" Drive for Rotary Table

A 24-inch hydraulic coupling driven from the main compound bypasses the master clutch and provides 250 hp for table and drawworks accessory drive.

By John N. Schuelke, WORLD OIL Staff

DRILLING PERSONNEL have long sought a low horsepower "soft" drive for rotary table and drawwork's functions excluding hoisting. Some attempts at this have been the independent drive for rotary tables, separately mounted and powered sand lines as well as split power rigs. A recent innovation for large rigs of 2000 horsepower has been the bypass or "run-around" of the master clutch. A 24-inch hydraulic coupling auxiliary drawworks drive is mounted on the No. 1 engine drive shaft so that the master clutch to the drawworks is bypassed. Three of these run-around couplings are presently in the field with the latest one being installed on a 2400-horsepower rig for International Drilling Company, N. V., destined for operations in Nigeria for Shell Oil Company.

This 24-inch coupling has scoop control and an independent, tube, heat exchanger mounted adjacent to the coupling. The cooling water is

Text Continued on Page 105

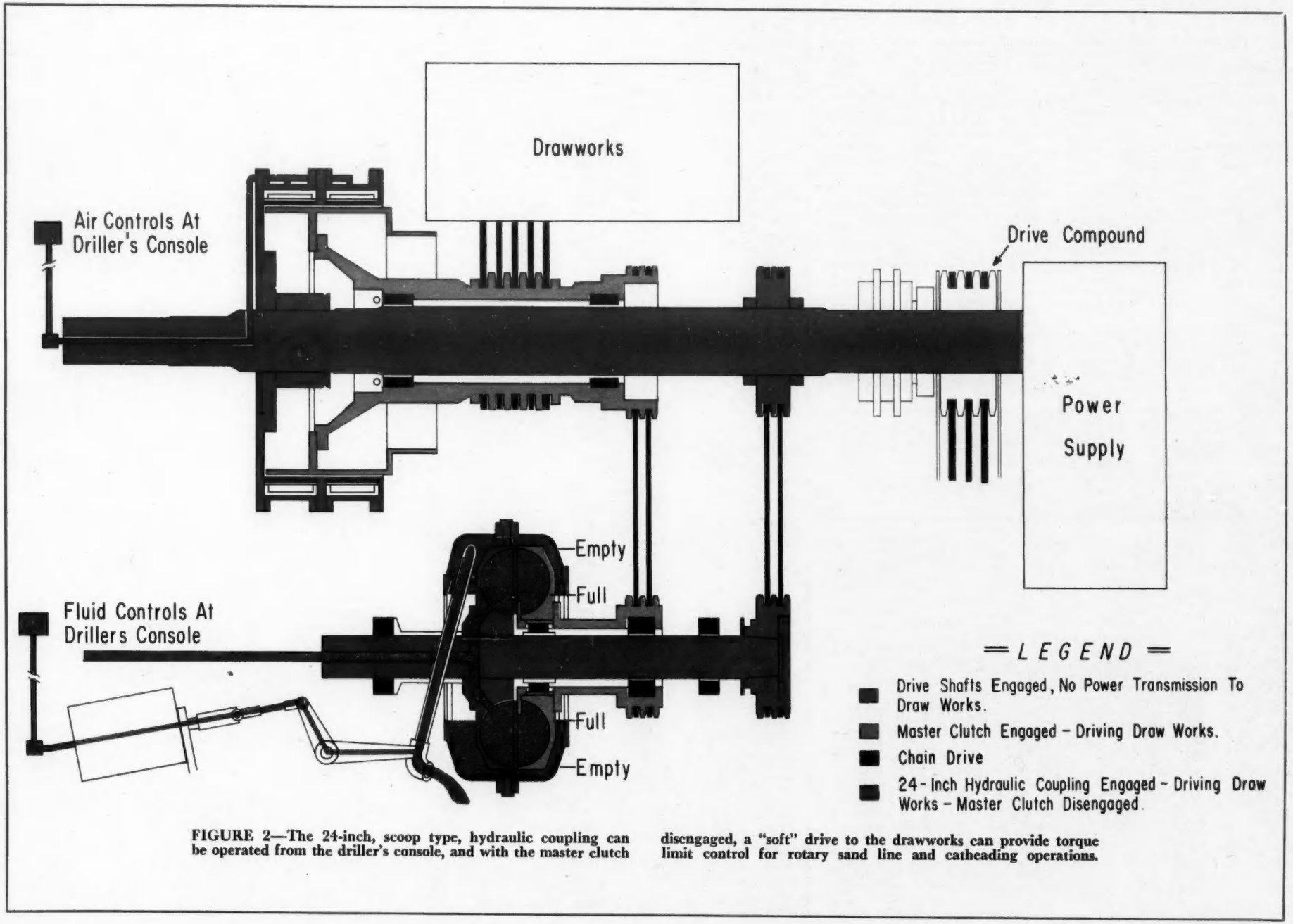


FIGURE 2—The 24-inch, scoop type, hydraulic coupling can be operated from the driller's console, and with the master clutch disengaged, a "soft" drive to the drawworks can provide torque limit control for rotary sand line and catheading operations.

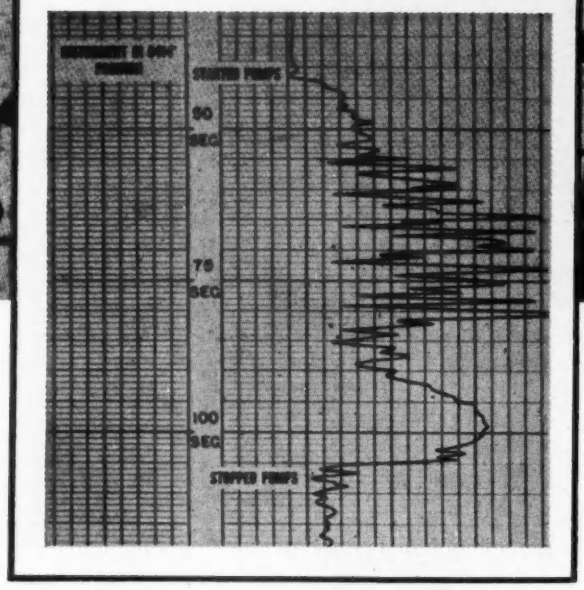


FIGURE 1—Time graph shows positive evidence of a fluid flow through the instrument after the mud pumps are started. This is a sure sign that the thief zone is below this point (oscillations are caused by pump strokes).

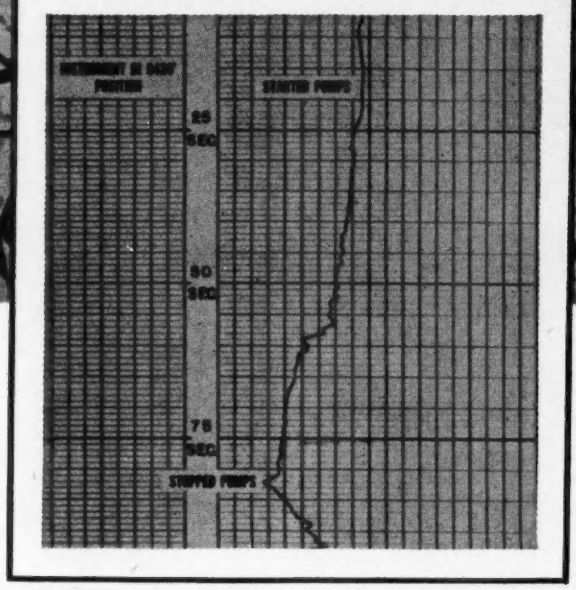


FIGURE 2—This time graph shows no fluid flow through the instrument upon starting the mud pumps. In fact, there is a slight drift to the left; hence, the thief zone must be above the instrument.

Instrument Pinpoints Lost Circulation

Run on wireline standard field servicing units, a new tool records down hole pressure differential to quickly and accurately locate "thief" zones.

A LOST circulation detector which pinpoints a "thief" zone and eliminates the loss of costly drilling fluids has been made available to the oil industry. The detector, a product of Gulf Research and Development Company, has been licensed to a major servicing company.

Effective treating of a thief zone can be accomplished only when it is known exactly where that zone is. The lost circulation detector can pinpoint this zone within one foot.

The detector has shown that while lost circulation often occurs at the point of bit penetration, it will, in many cases, occur at some distance above the drilling depth—sometimes as much as several thousand feet.

Also, the loss often takes place at the base of the surface or intermediate casing; indicating a defective cement sheath which can be remedied by a simple squeeze job.

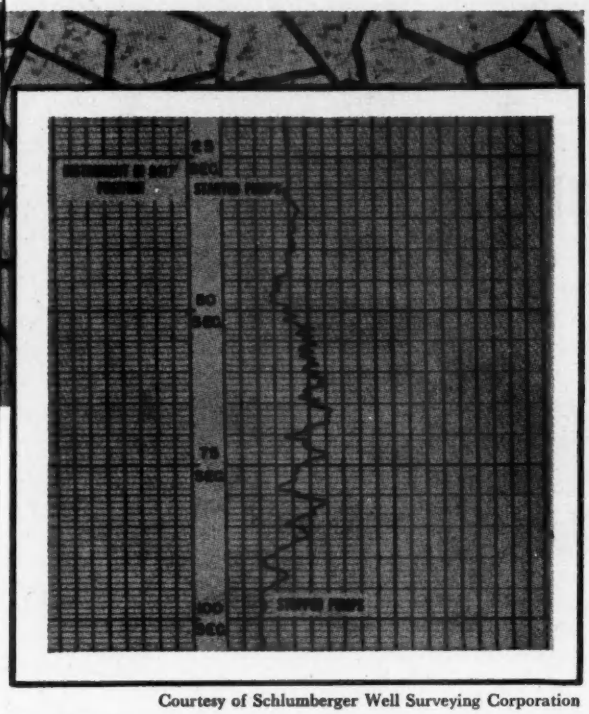
Ineffective and costly treatments are minimized when the zone of loss is correctly identified. Treatment can be applied at the exact location of the thief rather than covering hundreds of feet up or down the hole.

The time required to make a locating survey varies with depth. On the average, the survey can be accomplished in about an hour, exclusive of set-up time.

The detector is operated on a logging cable with standard field units that are now in use.

Detection of the thief zone through the instrument requires use of the mud pumps. A wire line lubricator is attached to the top of the surface casing. To take a reading, the instrument is stopped, the lubricator is closed around the cable, and the mud pumps are started. The pump strokes can be set to produce a flow rate for which the detector is most sensitive.

Starting just below the surface casing, readings are taken every 1000



Courtesy of Schlumberger Well Surveying Corporation

FIGURE 3—This graph shows a slight flow of fluid through the instrument as the mud pumps are started (much less than Figure 2); thus, most of the fluid must be entering the thief zone. The detector is within a foot of the zone of lost circulation.

Of course, several other checks were made in this well before locating the thief zone. In practice, these records need not be made at every test point. Immediately upon starting the pumps, the engineer can tell whether the detector is above or below the point of loss. The records can be taken after the approximate depth of the thief zone is established.

feet or so until a reading reveals no flow through the detector. This locates the thief zone between this point and the previous one up the hole which showed flow. A reading is then taken midway between these points; continually halving the interval until the lost circulation zone is pinpointed.

Actually, it is possible to pull the cable upwards through a closed lubricator for short intervals. Thus, after the thief zone has been located within a few feet, the detector can be placed below it, the lubricator closed, slowly pulled up. A change from "no flow" will pinpoint the thief zone the pumps started, and the detector exactly.

The detector is a thin-walled cylinder, 4½ I.D. Large vents at the top of the cylinder admit drilling fluid. The bottom of the cylinder is open through a 1½-inch swedge. When there is fluid motion through the cylinder in a downward direction, the flow is restricted by the small opening at the bottom. Thus the pressure inside the cylinder becomes greater than the outside.

In the center of the instrument is a window, consisting of slits cut through the cylinder wall. Stretched across the inside of the window is a rubber diaphragm which will move, depending on the differential pressure. When drilling mud flows through the cylinder downward, the pressure inside exceeds that outside, and the diaphragm is moved outward.

An electrode is in the center of the diaphragm, between two fixed electrodes on either side of it. Current flows between the fixed electrodes. Voltage is recorded on the diaphragm electrode. This voltage varies with the position of the electrode and is recorded at the surface. Thus there is an electrical signal which indicates movement of fluid through the instrument.

This detector will operate in any type of drilling fluid that is electrically conductive. No mud additive or treating is necessary except for pure oil base mud.

This tool promises to save a considerable amount of rig time and material cost in quickly and accurately locating zones of lost circulation.

—The End

"Run-around"

Continued from Page 102

obtained from the main cooling water system that is used for the hydromatic and drawworks brakes. This system provides a "soft" 250-horsepower drive for the rotary table with an infinite range of rotary speeds. Other drawworks functions such as sand line work or catheading can also be powered through the drawworks transmission by means of this 24-inch coupling.

There is instantaneous response from the driller's console to fill or empty the oil chamber to operate the coupling. The master clutch can also be engaged instantaneously while the 24-inch coupling is engaged without affecting it. In the past, contractors have talked of mounting a hydraulic coupling adjacent to the rotary table for a "soft" drive for the rotary table operations. However, by mounting this coupling behind the drawworks, it is possible to bypass the master clutch and provide speed and torque control for table operation as well as in sand line and catheading operations. This torque limit on the drawworks and table functions is preferable to putting all power through the master clutch.

Independent rotary table drives have proved to be ineffectual in most cases because the malfunction of the engine or its drive would take the rotary table out of service. If in the event this coupling were to malfunction, the master clutch can be engaged and the rotary table driven in a normal manner.

The addition of this run-around necessitates only a 24-inch increase in the length of the master clutch output sprocket shaft, and costs approximately $10,000 additional for rig equipment.

Here is a safeguard as well as a functional piece of equipment that will allow the main power of over 2000 horsepower to be directed toward driving the pumps; with this run-around taking only 250 to 300 horsepower for table operation. The safeguard feature also prevents sudden increases in torque from being applied to stuck pipe while rotating or to a sand line operations. Fine speed and torque control for such operations as washover, milling or coring operations are added advantages of this run-around coupling.

—The End

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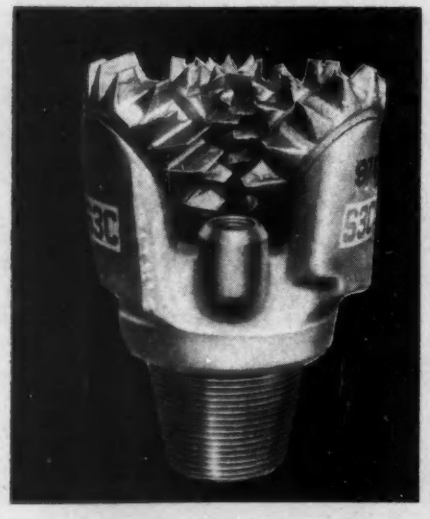

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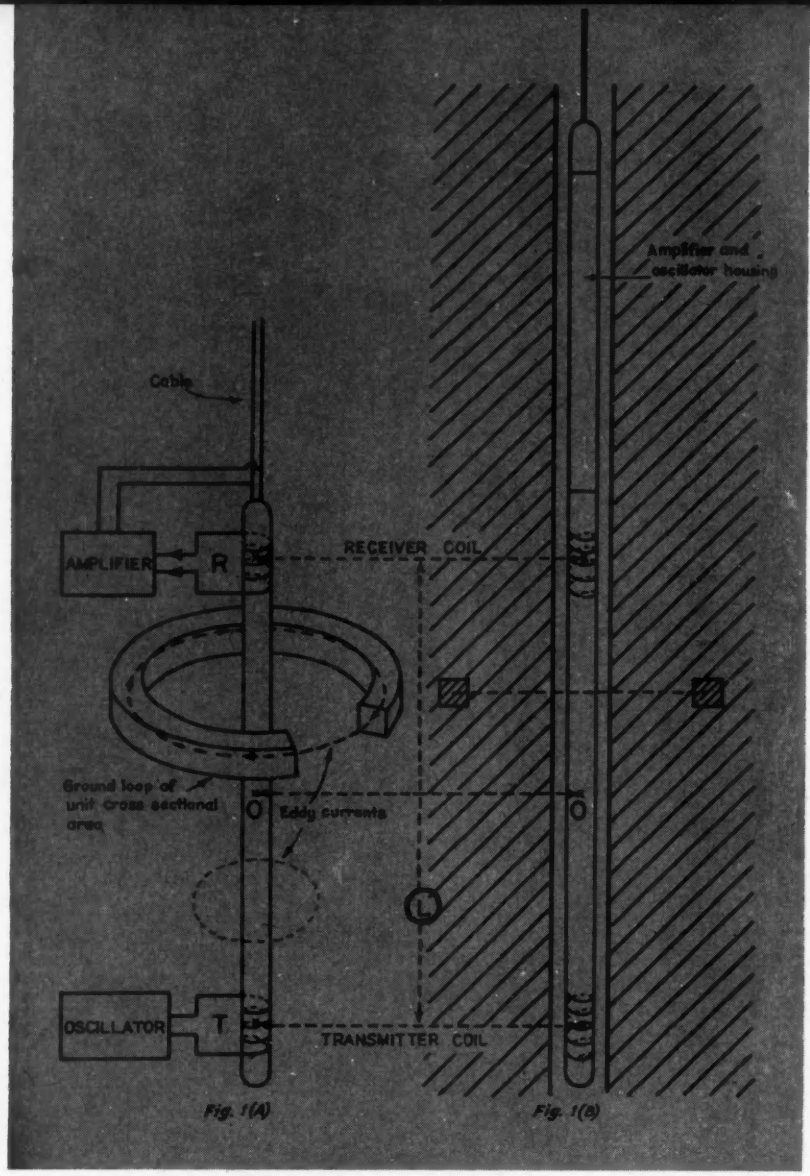


FIGURE 1—A schematic drawing of a simple induction logging system in which a transmitter coil and a receiver coil are wound coaxically on a supporting mandrel.

Induction-Electrical Logging in Oklahoma

The effects of the mud column, the invaded zone and the adjacent beds are minimized which allows more accurate determination of true formation resistivities.

By H. W. True
Schlumberger Well Surveying Corporation, Tulsa

INDUCTION LOGGING is a method which measures the conductivity as well as its reciprocal, the resistivity, of the strata traversed by a bore hole. This method has now been combined with electrical logging and has recently been introduced in Oklahoma.

Induction Logging as an auxiliary service has been offered for some time but on a limited scale.

Progress in instrumentation, incorporating vertical and lateral focusing, simultaneous recording of a spontaneous-potential, conductivity curve, a reciprocated conductivity curve and a short normal resistivity curve have now made possible the gradual replacement

of the conventional electrical log by induction-electrical logging in the majority of formations encountered in Oklahoma.

The basic advantages of induction logging over conventional logging are as follows:

1. The focused system of induction logging permits a greater depth of investigation without the loss of detail normally suffered with increased spacings in conventional logging.
2. The superior penetrating ability of the induction log provides a better determination of true resistivity.
3. The induction log minimizes the effect of the mud column.
4. Effects of adjacent beds on the bed under study are greatly reduced.
5. The measurements are very accurate in low resistivity beds.
6. It gives excellent resolution below thin resistive beds which are so detrimental to the conventional log.
7. The definition of beds and the determination of their boundaries are easier and more accurate with the induction-electrical log than with the conventional log.
8. It gives accurate readings on thin beds.
9. It requires no direct contact with the formations and, therefore, can be used to evaluate formation resistivity in cable tool holes, air-drilled holes and holes drilled with oil base muds.

The induction-electrical log has proven itself as a valuable tool to operators in Oklahoma, and has largely overcome many of the deficiencies present in the conventional system of logging.

Principle of Induction Logging. Since the principle of induction logging is not too well known to many, a brief description of the technique involved will be given.

In this method of logging, the formation surrounding the logging apparatus is energized by electromagnetic induction. An alternating current of an appropriate frequency is made to flow through a "transmitter" coil. The alternating magnetic field, due to this current, induces eddy currents in the earth surrounding the coil. These eddy currents in turn have their own magnetic field which induces an electromotive force in a "receiver" coil.

If the transmitter current is maintained at a constant value, the magnitude of the eddy currents is proportional to the conductivity of the earth, and consequently, inversely proportional to the earth resistivity.

Figure 1-A shows schematically a simple induction logging system in which a transmitter coil and a receiver coil are wound coaxially on a supporting insulating mandrel. The distance between the coils, "L," is called the "spacing."

An alternating current of constant magnitude and frequency is fed to the transmitter coil from an oscillator, which, with the amplifier, is actually housed in an electronic cartridge above the coil system. See Figure 1-B.

The voltage induced in the receiver coil by linkage with the magnetic field of the eddy currents is fed into an electronic system in which, after being amplified, it is rectified into direct current for transmission in the cable to the surface where it is recorded. The point of measurement is taken to be at a point "O" midway between the coils.

In addition to the two coils referred to above, called the main coils, the apparatus used at the present time has several additional coils. The characteristics of the main coils and of the additional coils, their distribution and their respective positions, are adjusted in order to minimize the effects of the mud column, the invaded zone and of the formations located above and below the bed under study. Such types of apparatus are appropriately referred to as "focusing sondes."

The most common types of instruments in the field at the present time are the 27-inch and the 40-inch focusing sondes. The former has a considerably smaller radius of investigation, but only a very slightly better vertical resolving power than the latter. To date the 40-inch sonde is the only type used in the combination induction-electrical log.

As has already been noted, the induction logging system does not require any direct contact with the mud or with the earth and can, therefore, be run in cable tool holes which are generally dry, in holes drilled with air (becoming a common practice in Oklahoma), in holes drilled with non-conductive oil base muds, or in holes drilled with fresh muds.

Recording the Induction-Electrical Log. The scales used for the presentation of induction logs are different from those of the conventional electric log. In induction logging the signal measured is proportional to the conductivity of the formations, therefore, the induction log is scaled in terms of conductivity.

The conductivity scale is linear and its zero is located at the right hand side of the log so that the deflections of the curves toward the left correspond to increases of conductivity, i.e., decrease of resistivity, as in conventional logs.

The unit of conductivity is the mho/meter; reciprocal of the ohm-meter. To avoid decimals in the evaluation of conductivity, the millimho/meter is used as the practical unit of measurement. For example, formations with resistivity values of 1, 10, and 100 ohm-meters would have corresponding conductivity values of 1000, 100, and 10 mmhos/meters respectively.

The induction scale, if calibrated in terms of resistivity units from left to right is hyperbolic, thereby emphasizing the low resistivities by amplification and compressing the high resistivities. The amplification of the low resistivities is extremely desirable in such formations as the "Mississippi Chat" "McLish" and "Burbank."

Present combination induction-electrical logging tools provide a self-potential, a 16-inch normal, a 40-inch conductivity curve, and its reciprocal, all recorded simultaneously.

The "reciprocated" curve gives the same measured values but with a linear resistivity scale making it easier to compare induction logs with conventional logs.

Bed Definition. The definition of beds encountered and the accurate determination of their boundaries is greatly simplified with the induction log. Sharp deflections occur exactly at the levels of the bed boundaries. The curve opposite a given bed shows practically no distortion. Excellent bed definition is obtained on beds as thin as three feet with the 27-inch curve and four feet with the 40-inch curve. The conductivity scale is most valuable in clearly pointing out lithological variations in shaly sections and is good in showing oil-water contacts which are characterized by large deflections of the curve.

Effect of Mud Column. The greater

Sold on past performance, Penrod powers its third drilling rig with CAT Diesel Engines

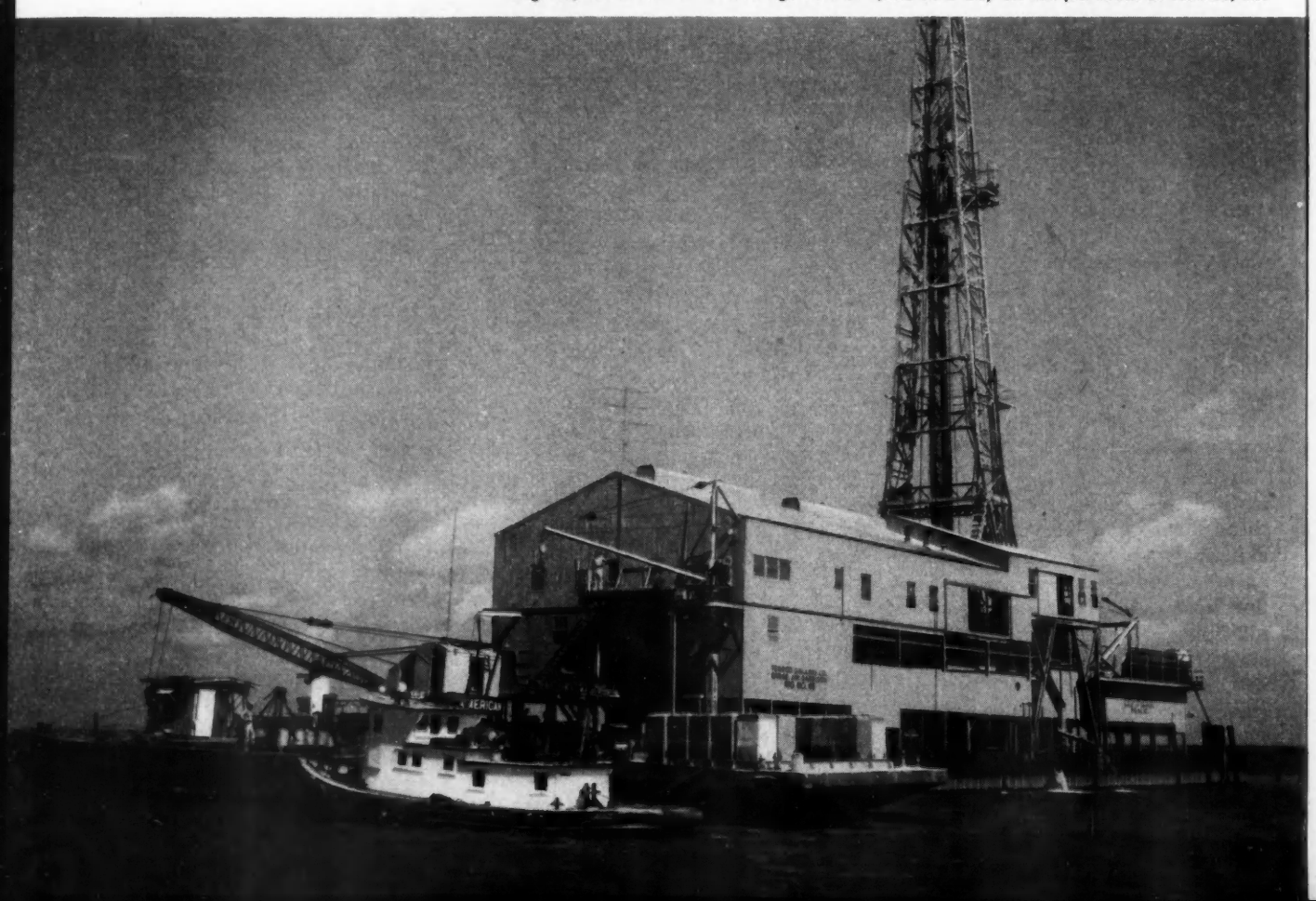
Penrod Drilling Co. of Shreveport, La., working Rig No. 45, fifty miles southwest of Houma in Cat Island Pass (on the southwest edge of Kye Island field) relies on Cat Diesel Engines in drilling better than 1,000 ft. per day. With four D397s, two D315s and two D342s, the "Jim Garrison" barge moved in on Sept. 14, spudded a 15″ surface hole and set 3,029 ft. of 10¾ surface pipe. On Oct. 31, they were out of the hole to run electric log at 15,177 ft. and cut a 9⅞ hole on the first well. Their best drilling time was 10,026 ft. in 10 days from spudding date. More than 1,000 ft. per day.

On this offshore drilling operation, Penrod compounds three of its Caterpillar D397 Diesel Engines to drive the Emsco drawworks. Two D315s and a D397 drive Gardner-Denver mud pumps, and two Cat D342 Electric Sets handle auxiliary power.

A big operator and investor in dependable equipment, Penrod can't afford to guess about drilling power. This Company *knows* from experience that Cat Engines are reliably rated and are available in a variety of power sizes for any drilling assignment.

Only two of the many "guts" features which make Cat Engines the best for drilling are cylinder liners and pistons. To give long periods between overhauls, Cat Engine pistons are balanced to close tolerances. Cast-iron bands support the top rings for extra strength, and rings are chrome-faced for

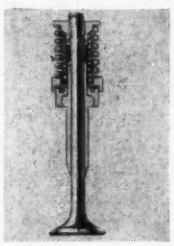
Penrod Drilling Company's "Jim Garrison" Barge, powered by eight Cat Diesel Engines, has drilled at an average rate of 1,000 ft. a day on this job south of Houma, La.



longer wear. Piston rings ride freely with minimum wear because Cat cylinder liners are honed and chemically treated to give long life. Cat wet-type cylinder liners maintain low piston temperatures and are easily changed if necessary.

For drilling power—from prime to auxiliary—call your Caterpillar Dealer today. He's that real good neighbor—the one who knows what he's talking about. And be sure to specify Caterpillar power for your drilling equipment.

Engine Division, Caterpillar Tractor Co., Peoria, Illinois, U. S. A.



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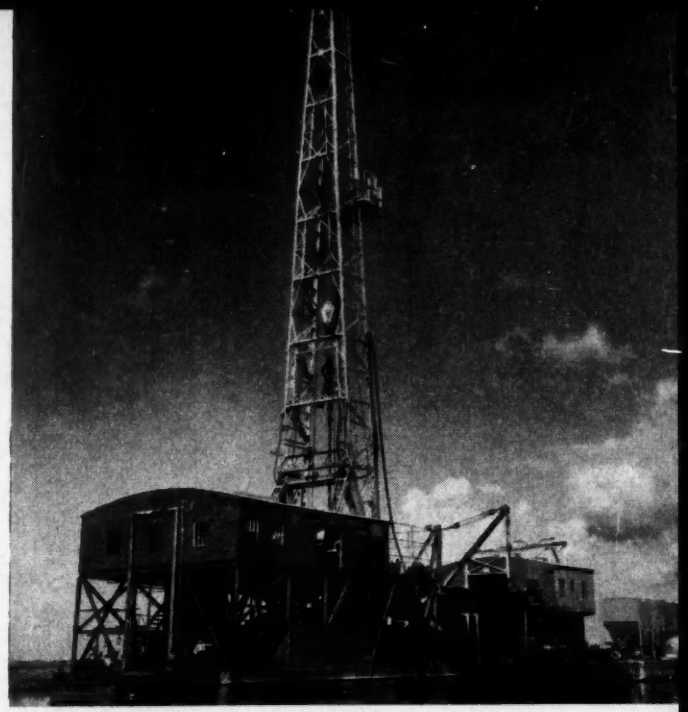
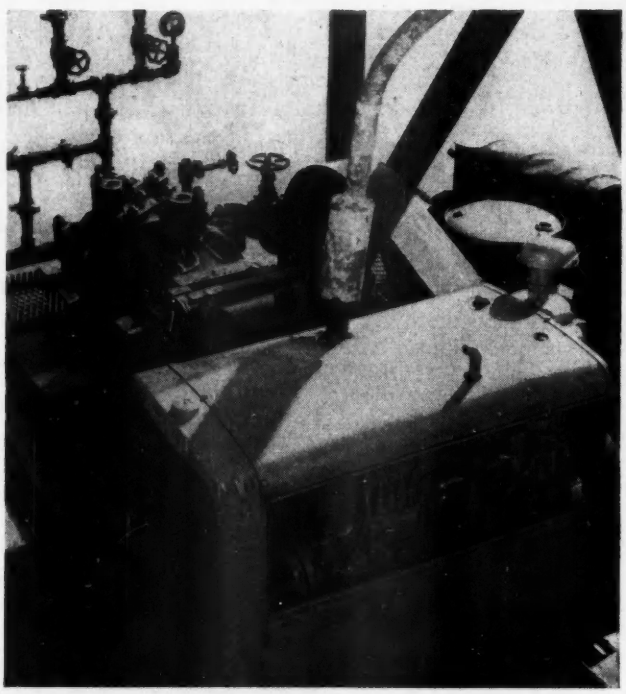
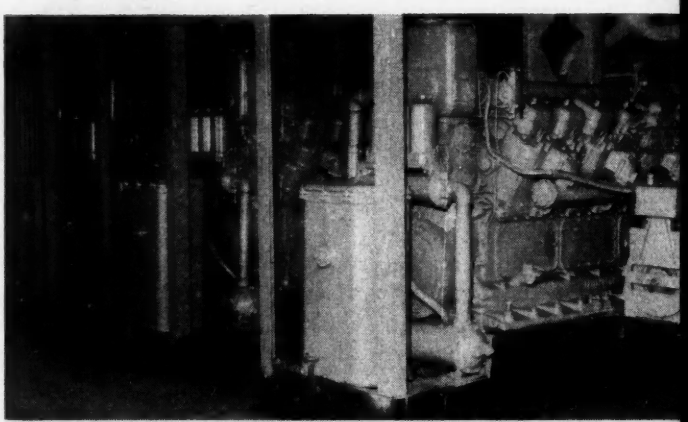


Penrod's Rig No. 41, drilling southeast of Port Sulphur, La., also is powered by Caterpillar. Two D397s are compounded to drive the drawworks, two additional D397s drive the mud pumps, two D315s drive Mission Water pumps, and a third D315 drives a Gardner-Denver water pump, with a Cat D315 Electric Set used for auxiliary power.

ENGINE POWER BY CATERPILLAR



This Caterpillar D315 Engine drives a water pump on Penrod's Rig No. 41 near Port Sulphur, La. One of many components which make Cat Engines dependable is aluminum precision-type bearings supporting the crankshaft. Each bearing has a thin coating of tin for proper bearing break-in for long engine life.



These three Cat D397 Engines are compounded to drive the Emsco drawworks on Penrod's Rig No. 45. Three additional Cat Engines drive the mud pumps and two Caterpillar Diesel Electric Sets furnish auxiliary power for the rig.

Dept. WO3, Engine Division
CATERPILLAR TRACTOR CO., Peoria, Illinois, U. S. A.

Send me more information about Caterpillar Diesel Engines for prime and auxiliary power in drilling operations.

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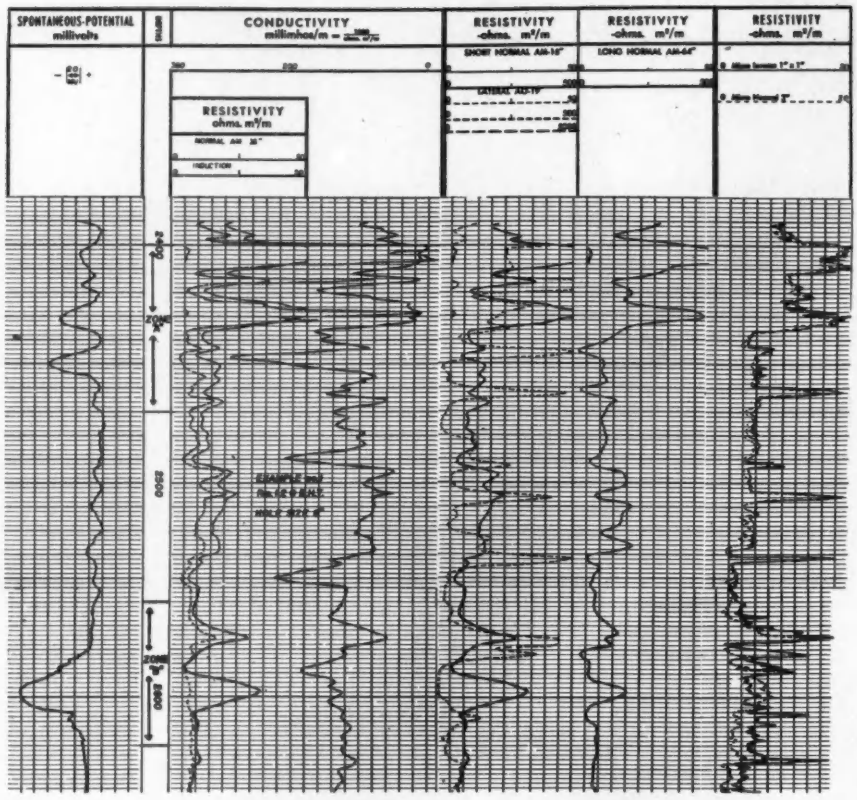


FIGURE 2—The induction-electrical log, the conventional electrical log, and the Micro-Log run through a portion of the Pennsylvania section in an Oklahoma well.

the ratio of formation resistivity to mud resistivity, the greater is the departure of the resistivity measured from the true resistivity. For hole diameter usually encountered in Oklahoma (7¾-inch to 9-inch) and muds of .5 ohm or greater, the bore hole effect is practically negligible with the 40-inch spacing tool so long as the formation resistivities do not exceed about 50 ohms. When the formations are very resistive, it is advisable to correct the measurements for the effect of the bore hole. This can be done by the use of computed correction charts.

In those wells drilled with oil base mud, cable tools, or with air, there is no correction to be made, except in cases where considerable hole enlargement occurs, a condition that is rare in Oklahoma formations.

Effect of Surrounding Beds on Bed Under Study. Due to the remarkable focusing power of the induction tool and its principle of operation, the measurements made on a given bed are much less affected by the presence of the surrounding formations than are the measurements made with conventional electric logs.

For a given bed thickness, the influence of the surrounding formations varies. This influence is dependent on whether the adjacent beds are more resistant or less resistant than the bed under study. Since the eddy currents induced in the earth have a tendency to circulate more freely through the most conductive media, then the influence of adjacent beds will be greater if they are more conductive than the bed under study. On the other hand, if the bed under study is more conductive than the adjacent beds, then their influence will be negligible.

If the resistivity of the surrounding beds R_s is appreciably lower than the bed under study (does not occur too often in Oklahoma formations) their influence becomes appreciable and has to be corrected for by appropriate charts.

In Oklahoma, interesting beds quite often occur immediately under thin resistive limestone streaks or in between several such lime streaks. The readings made opposite these interesting beds are greatly affected on the conventional electric log by the presence of the thin resistive limestones, which makes their evaluation extremely difficult. With induction logging these thin resistive streaks do not essentially affect the readings opposite the interesting beds and their correct evaluation becomes routine.

Effects of Invasion—The induction log is most useful for the investigation of permeable beds when the resistivity of the invaded zone R_i is greater than R_t, a common condition in many Oklahoma formations.

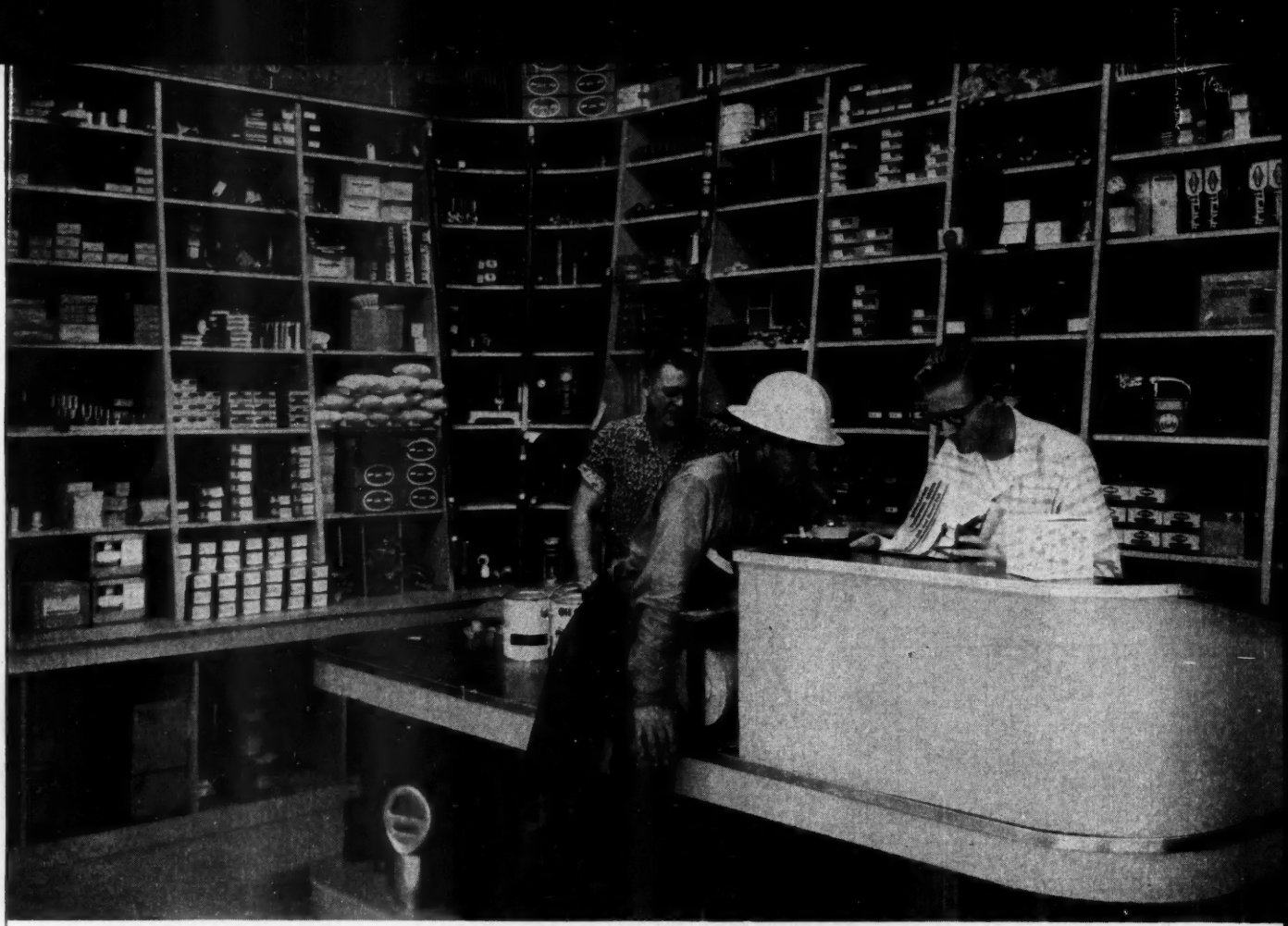
The most accurate results are obtained with the induction log when the mud resistivity R_m is at least 10 times as great as the connate water resistivity R_w. This condition is almost always fulfilled in Oklahoma since the formation waters are saline and the muds generally fresh. Interpretation may still be possible, even if the ratio R_m/R_w is as low as 4 or 5, providing the depth of invasion does not exceed three to four hole diameters.

When the invasion is deep, a correction should be applied to the measured resistivity to obtain R_t. To this end, the value of the resistivity of the flushed zone (R_{xo}) has to be determined by means of the MicroLog or MicroLaterolog. In addition, another resistivity measurement of intermediate spacing is necessary. With the present combination induction-electrical logging tool, a short normal curve is recorded simultaneously with the conductivity curve and can be used as the additional measurement. The value of R_t can be derived from the values read from the induction curve, the short normal curve, and from the value of R_{xo} with the help of appropriate interpretation charts. These charts at the same time give a good estimate of the depth of invasion.

It is important to remember that the induction device is particularly responsive to conductive material. Therefore, it is very efficient in identifying a water zone behind a sheath of very resistive invasion, even when the invasion depth is considerable. In this respect, the 40-inch sonde is always better than the 64-inch normal; it is also better than the 18-foot 8-inch lateral when the porosities are less than 12 percent.

In oil sands, deep invasion is not such a problem, since the invaded zone resistivity is usually rather close to the true resistivity.

Therefore, for the conditions commonly met with in Oklahoma, the 40-inch induction log is usually more efficient than conventional long spacing resistivity curves, regardless of bed



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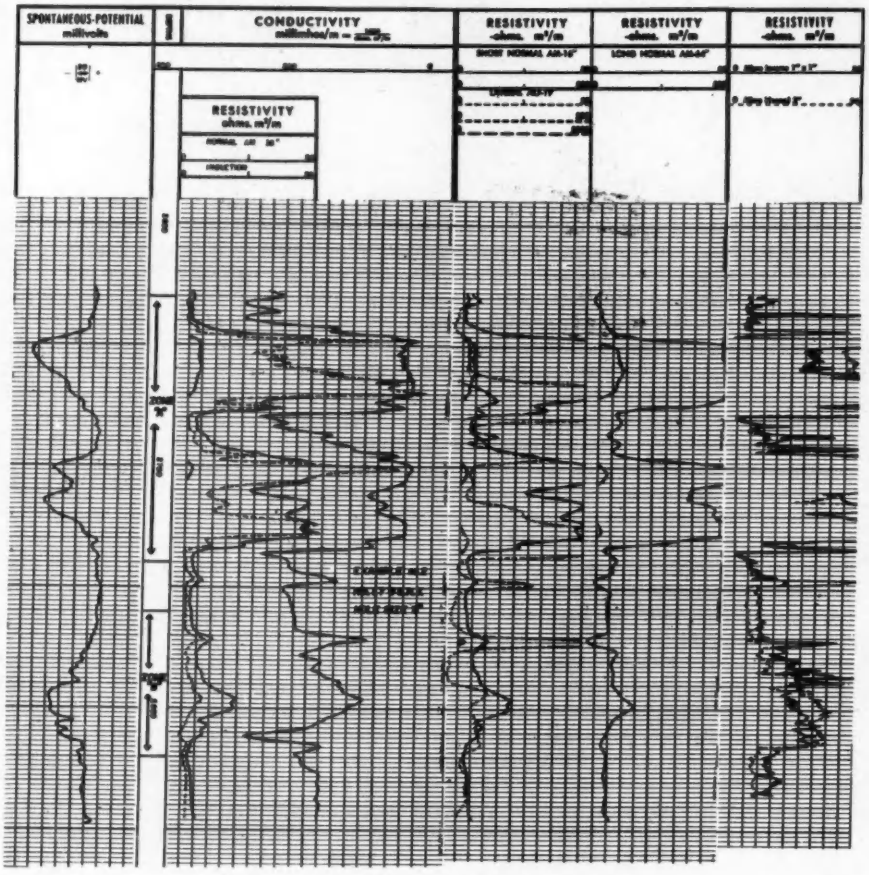


FIGURE 3—This is an illustration of the induction-electrical log, the conventional electrical log and the MicroLog recorded through a resistive limestone section in an Oklahoma well.

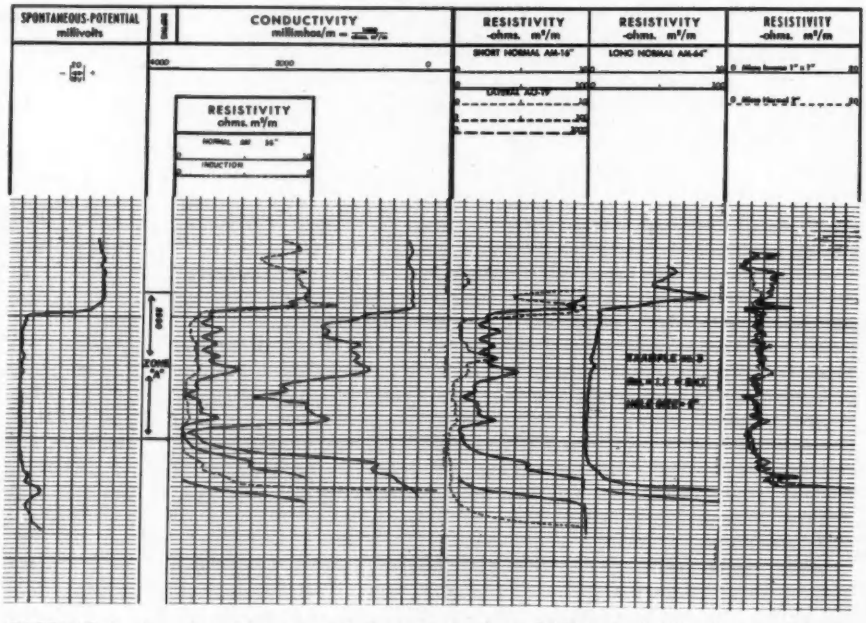


FIGURE 4—A series of logs recorded over a section of Mississippi "Chat" in Oklahoma that is characterized by extremely low producing resistivities.

thickness. Furthermore, the thin bed problems are largely eliminated.

Field Examples. Figure 2 is an example showing the induction-electrical log, the conventional electrical log, and the MicroLog run in an Oklahoma well through a portion of the Pennsylvanian section.

In zone "A," from 2400 feet to 2470 feet, the lithology varies quite widely. Observe the excellent resolution of these formational changes offered by the induction log through this zone.

The sand from 2444 feet to 2454 feet is located between two thin resistive beds. The short and long normals are reading too high due to the influence of these two resistive beds, and the lateral is shielded. The induction log is the only curve capable of evaluating the sand and clearly shows it to be water bearing.

In zone "B," at 2582 feet there is a thin resistive bed. The sand from 2590 feet to 2606 feet is within the shielded or "blind zone" of the lateral, hence the lateral is reading much too low a value of resistivity. The short and long normals are reading too high because of the presence of an invaded zone.

The induction log is the only curve that is giving an accurate reading over this bed and clearly shows the sand as water bearing.

Figure 3, zone "A," is an illustration of the induction-electrical log, the conventional electric log, and the MicroLog recorded through a resistive limestone section in an Oklahoma well. In zone "A," the section from 2640 feet to 2678 feet is known as the Big Lime and the section from 2696 feet to 2736 feet is the Oswego Lime.

In the Big Lime there appears a porous section from 2650 feet to 2660 feet. This section falls within the "decay" zone of the lateral curve which is reading much too low a value of resistivity. The short and long normals are reading too high because of the adjacent resistive beds. The values recorded by the induction log do not need any correction for bed thickness or adjoining formations. Also note the excellent detail over the entire section which is totally lacking in the conventional resistivity log.

In the Oswego Lime a combination of "decay" and "blind" zones is present on the lateral from 2698 feet to 2714 feet and the normals are reading too high as in the Big Lime section. The MicroLog shows the Oswego to be dense. The self-potential curve indicates that there are permeable and impervious streaks interspersed throughout the section. The induction log shows good definition throughout the section and greatly simplifies the interpretation of the Oswego section.

In zone "B," the interval 2790 feet to 2814 feet is the Prue sand. At 2772 feet note the thin resistive lime. This

thin resistive lime shields the lateral curve and causes a reflection peak to appear at 2793 feet right in the top of the pay sand. The short normal suffers from invasion and the long normal is reading too high due to invasion and surrounding bed effects. As a result it is quite difficult to ascertain whether or not the sand is productive. The induction log gives excellent readings of true resistivity through the sand and shows a well defined oil-water contact at 2806 feet. The well was perforated for production from 2788 feet to 2802 feet and produced clean oil.

Figure 4 is a series of logs recorded over a section of Mississippi "Chat" in Oklahoma. The Mississippi "Chat" is characterized by extremely low producing resistivities. "Chat" exhibiting less than one ohm resistivity can usually be classified as water bearing, whereas "Chat" that exhibits a resistivity greater than one ohm may well prove to be a commercial oil producer.

With the conductivity scale of the Induction log, which shows extreme detail for conductive beds, it becomes easy to read accurately very low values of resistivity. Such accurate readings of low resistivity are practically impossible with the conventional electrical log. This point is definitely shown in the example through zone "A." At 2495 feet there is a thin resistive bed which partially shields the lateral curve causing it to read too low. The short normal is affected by invasion and is reading too high a value of resistivity. The long normal may be fairly close to true resistivity but its lack of sensitivity and detail makes its use difficult. On the other hand, the induction log is reading true resistivity.

The conductivity curve with its extreme sensitivity to low resistivities affords excellent readings throughout the "Chat" section and assures a high degree of accuracy. An oil-water contact is clearly defined on the conductivity curve at 2526 feet.

Figure 5 illustrates a gamma ray log, induction log and a neutron log recorded in an air-drilled hole in Texas.

The induction log exhibits excellent detail and the gamma ray and neutron correlate well with it. Zone "A," from 2990 feet to 3066 feet is productive in this well.

Zone "B," from 3066 feet to 3130 feet shows a definite resistivity gradient from oil to water and a definite oil-water contact may be established at 3106 feet.

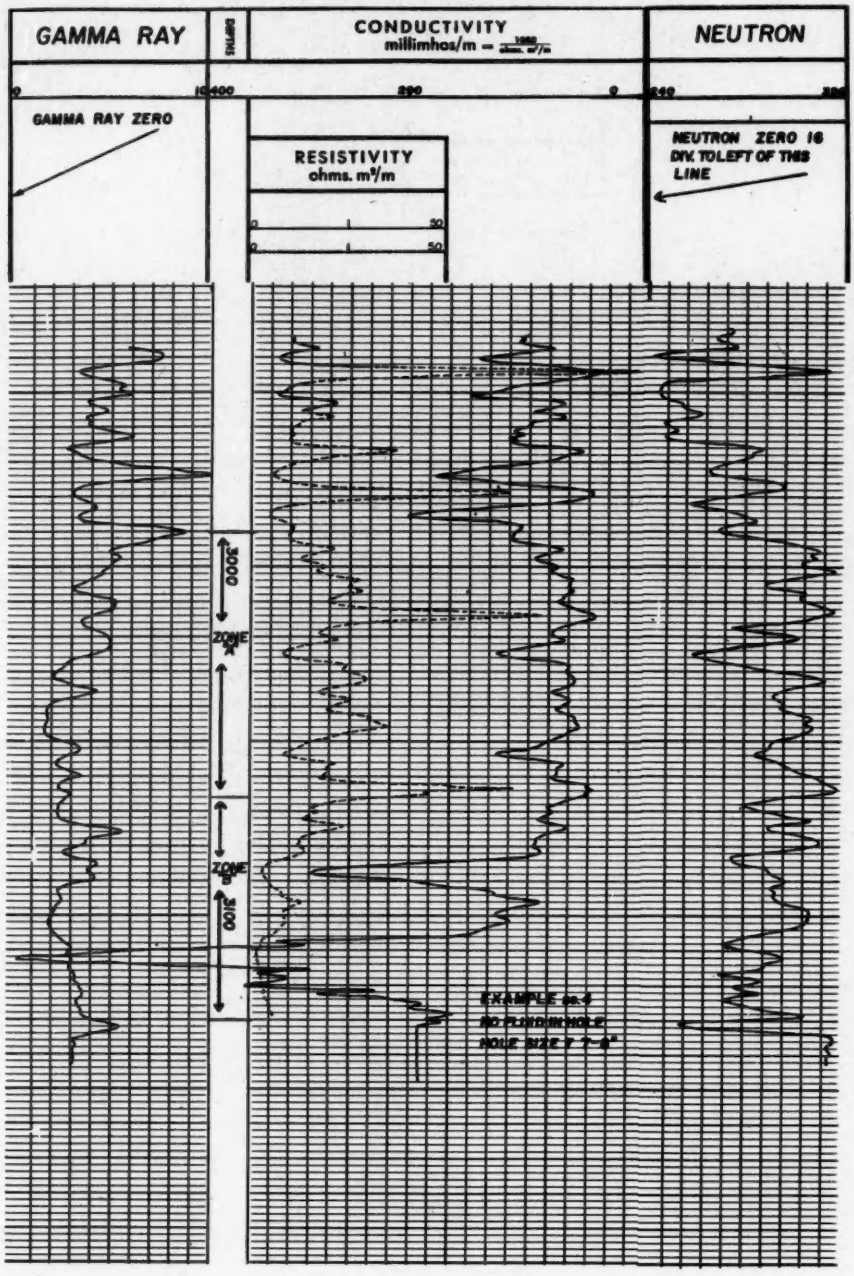


FIGURE 5—This illustrates a gamma ray log, induction log and a neutron log recorded in an air-drilled hole in Texas.

Figure 6 is an illustration of the gamma ray log, induction log and neutron log recorded in a cable tool hole in Oklahoma.

Zone "A," from 1950 feet to 2100 feet clearly shows the remarkable detail given by the induction log. Notice the excellent correlation of the gamma ray and the neutron with the induction log over this interval.

The zone from 1950 feet to 2000 feet is shown as very dense on the neutron and induction logs. Notice, also, the sharp bed definition afforded by the induction log in the zone 2022 feet to 2032 feet. In zones such as 2000 feet to 2020 feet and 2032 feet to 2100 feet the neutron shows the formations to be porous. The sands in these zones, however, are clearly defined as water bearing by the induction log.

Zone "B," from 2128 feet to 2160 feet, illustrates a producing section of the Burbank sand. The induction log shows that the sand is oil bearing from 2128 feet to 2156 feet with the best sand development from 2128 feet to 2138 feet. The lower part of the sand from 2138 feet to 2160 feet is very shaly as shown by the gamma ray. The

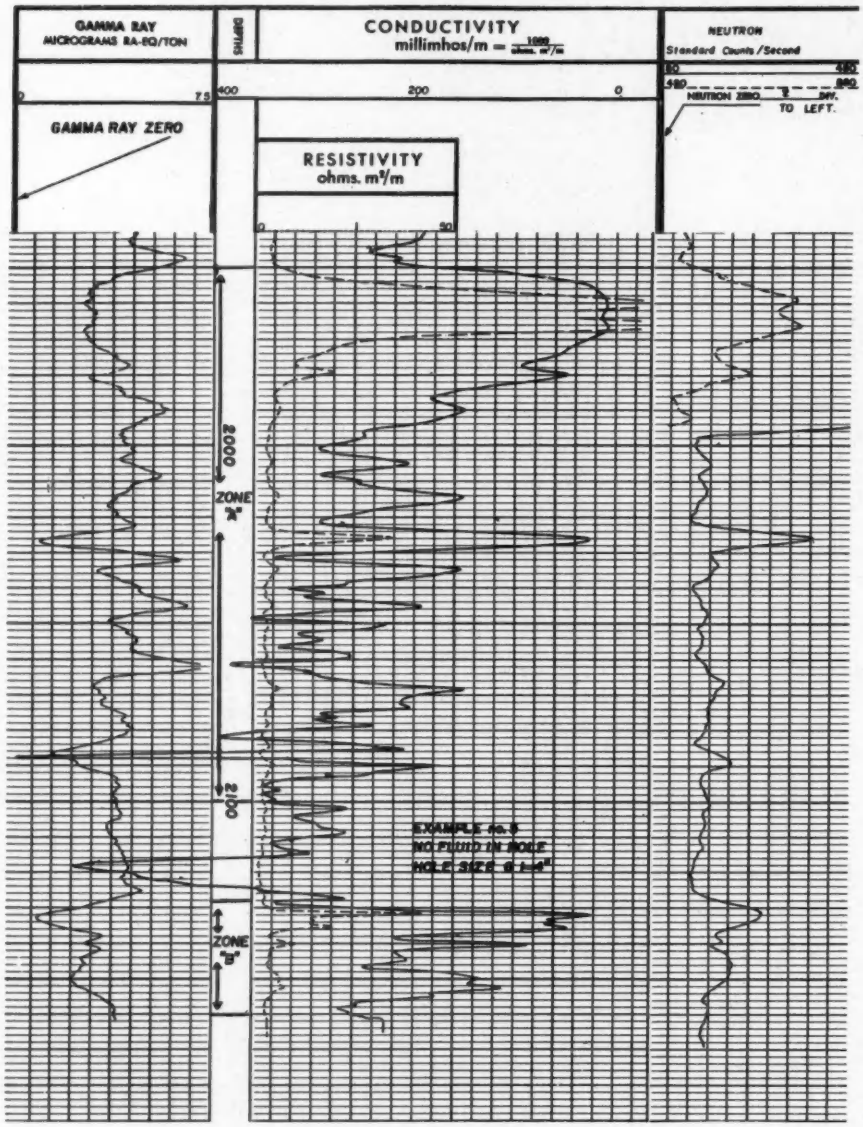


FIGURE 6—This is an illustration of the gamma ray, induction log and neutron log recorded in a cable tool hole in Oklahoma.

induction log shows excellent detail throughout the sand, and is reading a value very close to true resistivity.

Conclusions. Induction-Electrical logging is the most reliable method for the determination of true formation resistivities. It minimizes the effect of the mud column, the invaded zone, and the effects of adjacent beds on the bed under study.

Induction-Electrical logging provides accurate readings in low resistivity beds and in thin beds.

Induction-Electrical logging provides excellent resolution under thin resistive streaks that are so detrimental to the conventional log.

This method accurately defines beds and makes the determination of thin bed boundaries and oil-water contacts both easier and more accurate.

Induction logging is the only resistivity logging method which can be used for the surveying of cable tool holes, air-drilled holes, and holes drilled with oil base muds.

REFERENCES

[1] Doll, H. G.: "Introduction to Induction Logging and Application to Logging of Wells Drilled with Oil Base Muds," *Trans. AIME,* 186, 148.

[2] Schlumberger Well Surveying Corporation, "Review of Schlumberger Well Logging and Auxiliary Methods," (1949).

[3] Schlumberger Well Surveying Corporation, "Interpretation of Induction Logs," (1951).

The Knowledge Box

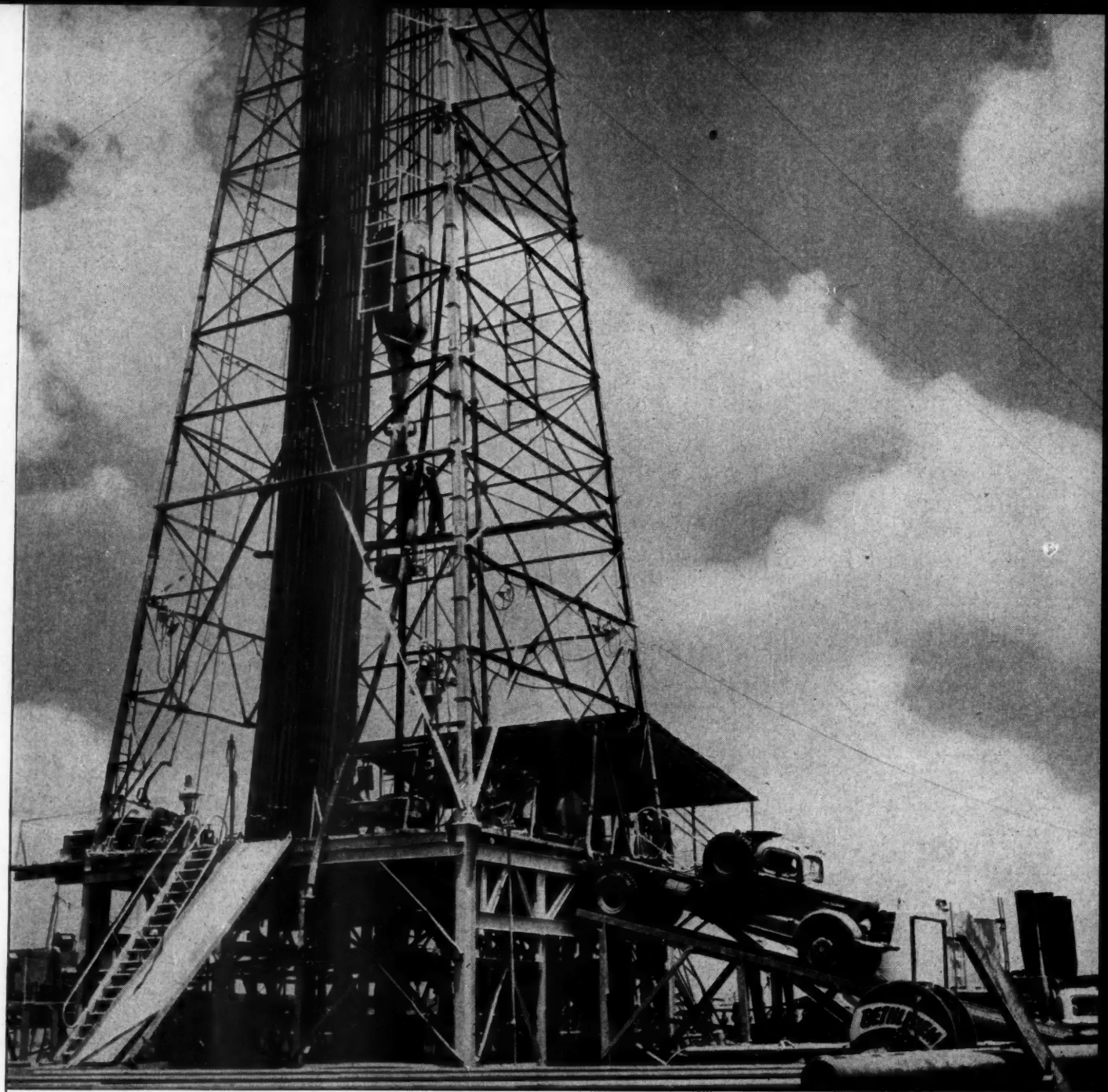
How well do you score?

A quiz for oil field folks. Score as follows: 0-4 (Weevil); 4-8 (Mud Doctor); 8-10 (Expert). One point for each correct answer.

1. Ph is a measure of: a. Viscosity; b. Chloride content; c. Basicity.
2. To convert from cubic feet to barrels (42 gal.) divide by. a. 6.5; b. 5.6; c. 7.5.
3. The specific gravity of clay is about: a. 1; b. 2.5; c. 4.3.
4. Silver nitrate is used to measure: a. chloride ion; b. sulfate ion; c. hydroxyl ion.
5. By each of the following oil fields write the state in which it is located:
   a. Spraberry Trend .....
   b. Crowley .....
   c. Ft. Stockton .....
   d. Golden Meadows .....
   e. Jennings .....

ANSWERS

1. c; 2. b; 3. b; 4. a; 5 a, Texas; b, Louisiana; c, Texas; d, Louisiana; e, Louisiana.



WIRE ROPE AT WORK

This was a deep one, a real challenge to the crew. When photographed, the rig had already put the hole down nearly 14,000 ft, and a long string of casing was being set. Drilled by Falcon-Seaboard, the well was in the Gulf Coast country near Ridge, Louisiana.

To guard against mishaps during the lowering and setting of casing, the crew installed a husky new Bethlehem Purple Strand rotary line. A 1¼-in. 6x19 rope with IWRC, the line had the high strength needed for the tremendously heavy loads involved. And of course, after the casing was set, this tough wire rope was available for drilling work, where it would add many thousands of ton-miles to its service record.

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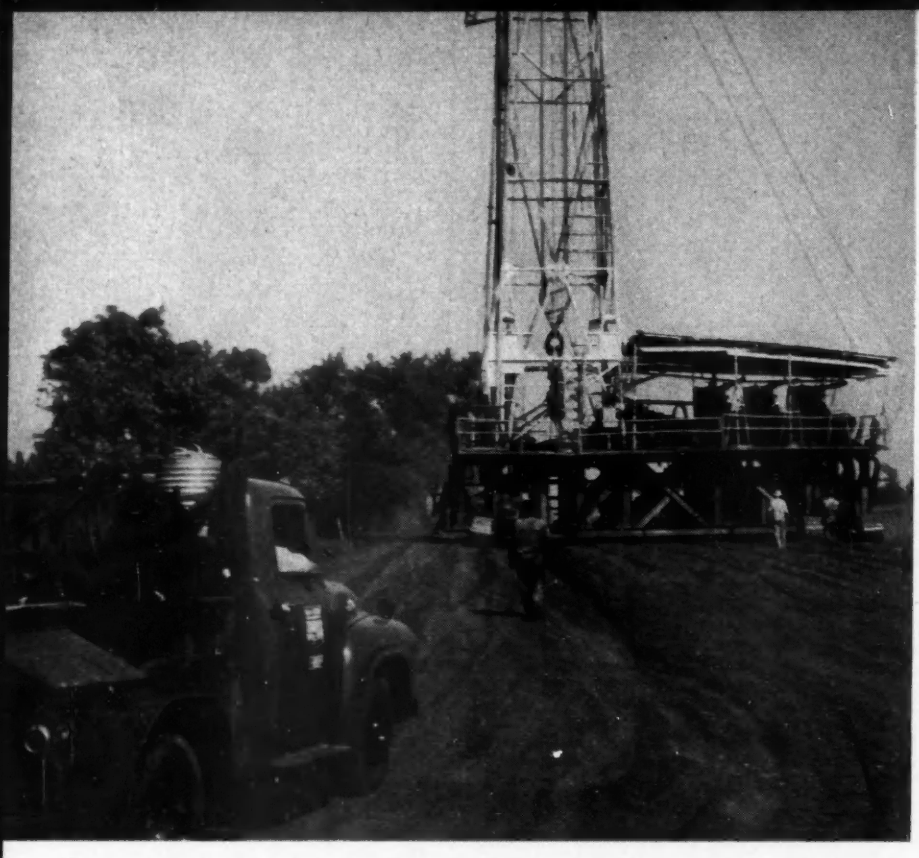


Crewmen check equipment. Crewman at left watches for tools or other articles which might fall from rig and which he picks up and places in the truck which follows.

Advance Planning Pays When Skidding a Rig

Reconnaissance of terrain, preparation of the rig, and determining the right kind of moving equipment should all be done in advance.

By Bill Jackson, President
Bill Jackson Rig Company, Oklahoma City

LIFTING 500,000 pounds or more of steel 12 to 18 inches above the ground and moving it mile after mile in almost any given direction over almost any type of terrain and setting it down again within a half inch of a well stake is a feat that can't help but be called "scientific."

There are many tricks in rig skidding as in any other business. Each job is personal and individual. Time and money can be saved and problems avoided simply by *planning ahead.* A typical skidding procedure runs something like this:

- Walk or drive the full length of the move noting the ground condition, the creek beds that will have to be filled, the ground slope, the telephone and electric wires that might be in the way, the fences that may have to be moved and the roads that may have to be built to clear a path.
- Check the rig for obstacles that may arise to slow down the crew.
- Make sure that all the rig moving equipment is on hand.

The term "skidding" is a big (and often time costly) misnomer. You don't *skid* a rig in any sense of the word—you roll it on heavy track wagons. Time after time, we have heard a farmer tell a tool pusher: "If I had known you were going to *roll* that rig, I wouldn't have charged you half as much for right-of-way. I thought you said you were going to *skid* it."

One way to get top efficiency and speed from crews is to pay a full day's wage . . . even if the move only takes an hour and a half. This makes crews work together and work efficiently. If one or more rigs are moved in one day, crews get paid a day's wage per rig moved. Where unusually long or hard moves are involved, crews receive double pay. This creates greater incentive and benefits to all concerned including the drilling contractor and the rig skidder.

The use of a one-ton pickup truck, equipped with jacks, hose and pumps will serve the same purpose as the so-called "box" setup. The disadvantage of the box setup is that it has to be transported to the rig, unloaded, cranked up and then reloaded. This is time-consuming. With all equipment mounted on one truck, about 45 minutes per move is gained. With the truck-mounted setup, the driver backs up to the rig, unloads the jacks and sets them in place. The hoses connected to the pump, are hooked up, and hydraulic lift oil is pumped to the jacks. As soon as the rig is raised and "loaded" the truck is released. Twenty-ton wagons which have a safety factor of approximately 10 to 1, and 50-ton hydraulic jacks are generally used.

The basic reason for skidding a rig instead of tearing it down and moving it is to save money, time and wear-and-tear on the rig. Some skid jobs are difficult but not impossible. Oklahoma is one of the roughest skid countries of them all. One skid, 7½ miles long, was completed in eight hours. The rig had to be moved from the West Doyle field near Marlow, Okla., across Table Top Mountain to the East Doyle field, crossing 4 high-lines, 4 telephone lines and 17 fences. Five tractors were used, be-

cause the rig had to cross rocky country almost all the way. One tractor cleared the road of large boulders, another filled ditches and leveled the land, while another followed to scoop out the ditches.

On a move in the Velma field near Duncan, Okla., the rig was skidded through soft, muddy marshland in a wooded area. It was necessary to "pave the way" with several thousand feet of 3-inch by 12-inch oak boards. Here advance planning paid off. Had the way not been paved, the rig would have bogged down thus losing much valuable rig time.

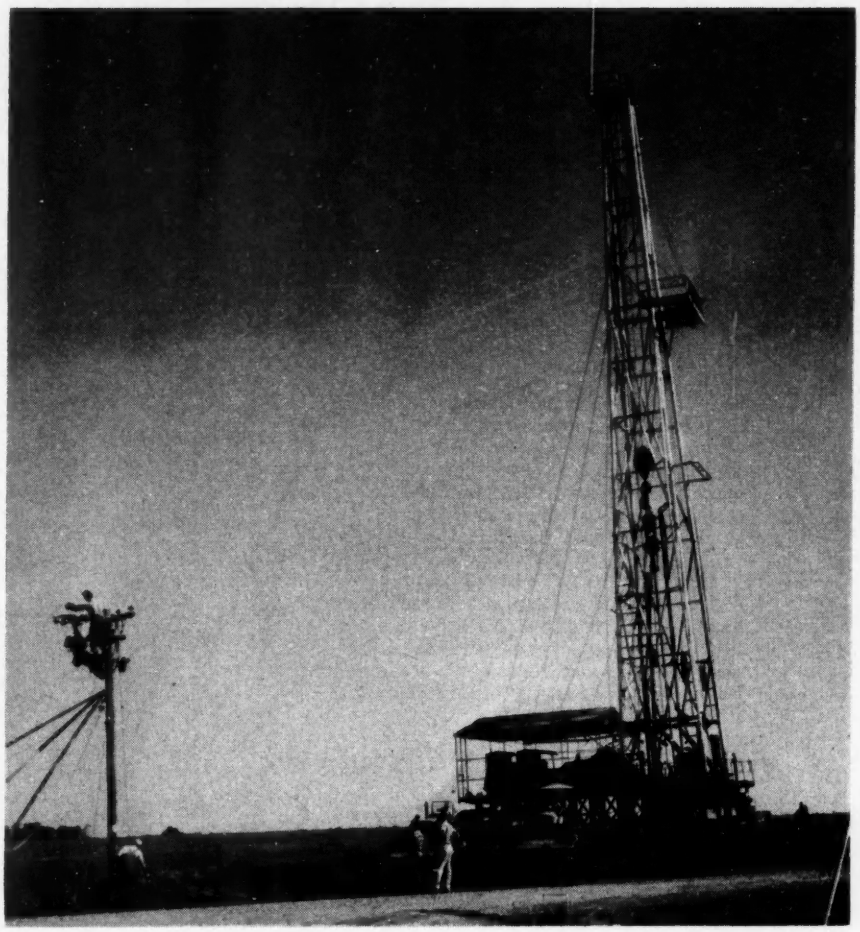
Breaking a rig loose from the matting is sometimes difficult. A technique used by one company makes this job a lot easier. When skidding a rig that does not have a removable section in the substructure, it is necessary to slide the rig clear of the christmas tree, and break it loose from the mat by tying all of the power onto one corner of the rig. After the break (usually several inches) the power is redistributed to two corners and the rig is dragged past the christmas tree before loading. This method saves about an hour per move. The usual practice is to raise the rig to break it loose, place greased boards underneath, slide it past the christmas tree, and then jack it up. This necessitates setting the jacks twice instead of once as in the technique described above.

Valleys and canyons present problems. At Short Junction it was necessary to move a rig down a hill that was steeper than normal. To prepare for this incline, 12 inches of wood were placed between the wagons and the bottom of the beam in front and six inches between the top of the beam and the rig. A minimum amount of wood was placed in the rear. This gave about 12 inches differential between the front of the rig and the rear. The rig still developed quite an angle going down the hill, but it may have crowded the center of gravity if it hadn't been loaded as it was. When this kind of hill move is necessary, it is usual to attach a guy line from the middle of the rig to a truck following, as an extra safety factor.

With careful advance planning most rigs can be moved at the rate of approximately one mile per hour, which includes moving the tools. Skidding, can save as much as $3000 to $4000 per move over tearing down.

—The End

Specially equipped one-ton pickup prepares to set jacks and unload rig.



Race against time. In this move which involved a power line the rig skidders were given exactly 30 minutes to take down the lines, move the rig and put them back. They beat the deadline by three minutes.

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The Generalized Kozeny-Carman Equation

Its application to problems of multiphase flow in porous media

Part 1—Review of Existing Theories

Various explanations have been suggested in the past for multiphase relative permeabilities. These have centered around the much misunderstood "tortuosity factor." Their theoretical and experimental basis is systematically presented.

By M. R. J. Wyllie and G. H. F. Gardner
Gulf Research and Development Company, Pittsburgh, Penn.

SINCE DARCY derived his famous equation a century ago many workers have studied the way in which fluids flow through porous media. Much knowledge has accumulated; a review of the literature pertinent to the present paper was sponsored by the AIME in 1951.[1] Since that time two monographs have appeared.[2,3] Nevertheless a quantitative understanding of the problem has not been attained and a comparison of the monographs mentioned will reveal that significant differences in both emphasis and beliefs exist between their authors.

Kozeny-Carman Equation. The derivation of this equation has been given in detail in several publications, Kozeny[4] and Carman.[5]

Poiseuille's law is written in the form

$$u_e = \frac{m^2}{k_o} \cdot \frac{\Delta P}{\mu L_e} \qquad (1)^*$$

To apply the equation to a porous medium, it is assumed:

(a) that the porous medium consists of one straight capillary of complex shape oriented in a direction parallel to that of macroscopic flow;

(b) that the mean hydraulic radius of this capillary can be defined by the ratio of internal volume per unit bulk volume ϕ, to internal surface per unit bulk volume S, i.e., ϕ/S;

(c) that capillary shape, though complex, is such that it has a shape factor k_o, which lies in the range 2.0-3.0. A figure of 2.5 is conventionally assumed;

(d) that the porous medium is uniform and isotropic and, in consequence, that the area available for flow, normal to the direction of macroscopic fluid flow, is ϕ per unit bulk area;

(e) that first, because the area available for fluid flow within the porous medium is restricted and, secondly, because it is qualitatively apparent that the fluid is constrained from flowing in straight lines through the medium, the actual average fluid velocity within the pores u_e is given by (u/ϕ) (L_e/L). Here u is the macroscopic or approach velocity of the fluid, L is the actual length of bulk porous medium through which the fluid flows and L_e the apparent length in the direction of macroscopic flow.

If these assumptions are incorporated in Equation (1) and the result compared with Darcy's Law,

$$K = \frac{\phi^3}{2.5\,(L_e/L)^2 S^2} \cdot \qquad (2)$$

Equation (2) is the so-called Kozeny-Carman equation. The Kozeny-Carman constant, k, is the product (2.5) $(L_e/L)^2$. In this dichotomy, as noted above, 2.5 is a shape factor. The quantity $(L_e/L)^2$ has been called the tortuosity.

Assumption (a) is the most radical and, superficially, the most attractive feature of the theory; but it also curtails its general applicability. All pores in the medium are considered as one pore. This complex pore has a cross-sectional area per unit bulk area of ϕ normal to the direction of macroscopic flow and an effective (but otherwise undefined) length parallel to the macroscopic flow

* Nomenclature at end of Part 1.

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direction that exceeds the actual physical length by the ratio (L_e/L).

The Kozeny-Carman theory is thus based on a capillaric model. Ostensibly the model is not that of a bundle of straight capillary tubes; in fact the model has this form if all tubes are identical. It has also been said[3] that the Kozeny-Carman theory, by concentrating on the flow through an area normal to the direction of macroscopic flow, ignores the tangential component of fluid velocity [assumption (d)]. This is a misunderstanding of the theory. In the Kozeny-Carman model it is expedient to concentrate on one property of an isotropic medium which is evident theoretically and has been verified experimentally, viz., the constancy of the area ϕ exposed in any unit cross-sectional area taken through the medium. Tangential components of velocity are then absorbed for convenience in the much misunderstood parameter tortuosity since these components are, in the model, equivalent to an increase in the apparent length of the flow path followed.

The Kozeny-Carman model is essentially an analogue model. It can have a pretense of rigour only if applied to a medium which possesses pores of identical size. From a practical standpoint, because of assumption (c) and the possible variations in the quantity $(L_e/L)^2$, some small variation of pore sizes can be tolerated without the introduction of errors that are appreciable. This limitation upon the applicability of the theory was fully realized by Carman.[6] Other limitations upon the theory mentioned by Carman, for example the absence of molecular slip effects and sealed pores and the necessity for a laminar flow regime, are implicit in all aspects of this discussion and will not be dwelt upon further. But a substantially uniform distribution of pore sizes such as generally exists in unconsolidated systems of particles is a fundamental requisite. If pore sizes are not uniform in a prototype, the Kozeny-Carman model must break down seriously. Because the quantity of fluid flowing through a capillary, according to Poiseuille's Law, is proportional to the fourth power of the capillary radius, the quantity flowing through a medium containing both large and small pores will be dominated by the flow capacity of the large pores. The surface area, S, on the contrary, will be powerfully affected by the large surface to volume ratio of the small pores. The Kozeny-Carman model purports to disregard the presence of individual pores by lumping all pores together in the single hydraulic-radius term ϕ/S. In fact it can only do this with any precision if the individual pores are all identical and with an accuracy which is probably acceptable practically if the range of pore sizes is small. While it is difficult to define the latter statement quantitatively, it would appear that most unconsolidated particle aggregates are systems to which the Kozeny-Carman model may be applied. It is appropriate to observe that it is not essential for reasonable uniformity of pore size distribution that all particles in an aggregate be of the same size. This has been demonstrated experimentally by Wyllie and Gregory;[7] what is important is that the distribution of particle sizes be within certain limits.

In natural consolidated porous media, i.e., porous sedimentary rocks, pore sizes vary greatly and the Kozeny-Carman model is no longer directly applicable. It is for this reason that the attempt was made by Wyllie and Spangler[8] to generalize the Kozeny-Carman equation by taking explicit account of variations in pore size.

Generalized Kozeny-Carman Equation. In order to incorporate terms descriptive of pore size in any modification of the Kozeny-Carman equation, it is necessary first to define what is meant by the sizes of pores in a porous medium. This is not easy. Scheidegger[3] has recently discussed the problems that abound when the deceptively simple term "pore size" is used. He suggests that the pore diameter may best be defined as the diameter of the largest sphere which will fit within a pore. This is an acceptable definition with but one drawback; a method of making the appropriate measurement is unknown. The only practical alternative is to use some measure of pore sizes and their distribution. Two acceptable techniques which give data reflecting on the distribution of pore sizes —or at least the sizes that control the entry of fluids—are capillary pressure curves for the injection of mercury into an evacuated porous medium or the injection of a nonwetting phase into a porous medium saturated with a wetting fluid. Both techniques are sufficiently well known to merit no further description. Both give comparable data. Both, in the view of the writers, are by their nature particularly suited to the problem. This view is based on the possibility that the factors affecting the entry of fluids into pores are similar to those which influence the flow of fluids through them.

Accepting the pragmatic view that an appropriate measure of the sizes of pores and their distribution can be obtained from conventional capillary pressure curves, can this information be usefully applied so as to refine the Kozeny-Carman model? This would seem to be possible as shown herein; but if it is done it is achieved by dispensing with a cardinal tenet of the original Kozeny-Carman model. The original assumption that the quantity ϕ/S is a convenient measure of a fundamental property of a porous medium must be discarded.

The approach used by Wyllie and Spangler was based on theoretical and experimental data adduced by Carman[9] to show that

$$S = P_c\phi/\gamma \qquad (3)$$

in systems of uniform pore size.

If Equation (2) is also held to be accurate for systems of uniform pore size, progress may be made as follows. View a real porous system (in which the sizes of pores differ) as being composed of a number of interconnecting media each of which is composed of pores of uniform size. The porosity of each "ideal" medium will be less than the total porosity, ϕ, of the real medium. If an air-water capillary pressure curve is used as a measure of pore size, the porosity of each ideal medium will be $\phi\Delta S_w$ where ΔS_w is a small increment of wetting-phase (water) saturation over which the capillary pressure, P_c, may be considered constant.

Combining Equations (2) and (3) gives for the permeability K_i of each ideal system

$$K_i = \frac{(\phi\Delta S_w)\gamma^2}{k\,P_c^2}$$

The quantity of fluid passed by each ideal system may be represented as ΔQ where

$$\Delta Q = \frac{K_i\Delta P}{\mu L} = \frac{(\phi\Delta S_w)\gamma^2}{k\,P_c^2} \cdot \frac{\Delta P}{\mu L}$$

The sum of all the quantities ΔQ will be equal to Q,

the total quantity of fluid flowing. The quantity Q in turn is related to the permeability K of the real medium by Darcy's Law. Thus

$$Q = \Sigma\Delta Q = \frac{\Delta P}{\mu L} \cdot \frac{\phi\gamma^2}{k}\sum\frac{\Delta S_w}{P_c^2} = \frac{K\Delta P}{\mu L} \therefore K = \frac{\phi\gamma^2}{k}\sum\frac{\Delta S_w}{P_c^2}$$

$$= \frac{\phi\gamma^2}{k}\int_0^1 dS_w/P_c^2 \qquad (4)$$

In the derivation of Equation (4) it must be observed particularly that the Kozeny-Carman constant k was considered uniform for all sizes of pores, i.e., it was not included in the summation $\Sigma\Delta S_w/P_c^2$. This step was also followed by Burdine, Gournay and Reichertz[10] in the derivation of the permeability of a model composed of parallel circular capillaries of size and number determined by mercury injection. Assuming that k is constant is a step not easy to justify. The assumption is based on the following view. In the derivation of Equation (4), the model used implies that the fluid which flows through each ideal medium, for reasons of continuity of path, necessarily flows also through all other ideal media. Thus the constant k, which combines a path length and a shape factor term, will be the same for each ideal medium unless the shapes of pores are uniquely related to their sizes; and the latter, in a sedimentary rock, for example, does not seem probable. The final justification of Equation (4) must rest upon experiment. Such experimental verification of the equation as has been obtained will be considered in the next section. An alternative derivation of Equation (4) which is based on a more refined model of a porous medium will also be given.

Pore Parameters From Electrical Measurements. The Kozeny-Carman equation, both in conventional and what we have called the generalized form, is an equation which is based on a particular model of a porous medium. This model consists either of a single tube or, in generalized form, of a number of fictitious tubes which are oriented parallel to the direction of macroscopic fluid flow. The tube or tubes are characterized by an area ϕ per unit bulk area perpendicular to the macroscopic direction of flow and by an apparent length L_e. The ratio $(L_e/L)^2$ or tortuosity is sometimes given a surprising physical significance, e.g., Cornell and Katz[11] imply that the area available for flow in a porous medium when multiplied by the ratio (L_e/L) must give the total pore volume. Such a model of a porous medium consists of tubes which are not oriented parallel to the direction of macroscopic fluid flow. It may be conceived as intertwined macaroni and spaghetti; it has little resemblance to the Kozeny-Carman model. In the latter the tortuosity reflects principally variations in the area available for flow of fluid in individual pores and at the connections between pores.* The actual increase in path length caused by the sinuosity of flow around grains—the conventional explanation of tortuosity—is probably trivial by comparison with areal effects.

If this tortuosity is to be independently measured, it is essential that the above be borne in mind. The interpretation of any experimental data purporting to measure the tortuosity applicable in the Kozeny-Carman equation must be based on a consistent model. For example the model used by Cornell and Katz to calculate tortuosities is not necessarily a poorer model than that of Kozeny-Carman. It is, however, quite a different model. As such it is not legitimate to use a Cornell-Katz model in evaluating parameters in the Kozeny-Carman equation.

The Kozeny-Carman model may be used to interpret data obtained by measuring the increase in the apparent resistivity of an electrically conducting fluid when this fluid fills the pore spaces in a porous medium. A similar figure can be obtained by measuring the apparent decrease in the diffusion coefficient of a substance that saturates the medium.

It is assumed that the apparent increase in electrical resistivity is the result, on the Kozeny-Carman model, of two factors. The first is the availability of an area per unit area perpendicular to the apparent direction of current flow of only ϕ; the second, since the area factor is insufficient to explain fully the increased resistivity, is considered to be an increase in path length in the apparent direction of current flow, i.e., L_e. If F is the apparent relative resistivity increase (formation factor), it follows that

$$F = \frac{(L_e/L)}{\phi}$$

$$\text{or } (L_e/L)^2 = F^2\phi^2 \qquad (5)$$

Since the model assumed for the treatment of resistivity is identical to the Kozeny-Carman model, it is assumed that the two tortuosities will be either identical or reasonably similar.

However, it is not probable that the two tortuosities are identical. This view is based on the fact that flow of current is proportional to the first power of pore area while flow of fluid depends upon the second power. As previously noted, the Kozeny-Carman tortuosity term, from the nature of the model assumed, is primarily a reflection of variations in areas available for flow in and between pores. The acid test of the validity of the assumption must, nevertheless, rest upon the agreement between calculated and experimental data. Combining Equations (4) and (5) gives

$$K = \frac{\phi\gamma^2}{2.5\,(L_e/L)^2}\int_0^1 dS_w/P_c^2 = \frac{\phi\gamma^2}{2.5\,(F\phi)^2}\int_0^1 dS_w/P_c^2 \qquad (6)$$

Data available for testing Equation (6) are few in number. Fortunately a number of careful experiments have recently been reported.[12] In these 24 natural sandstones and limestones and one synthetic alundum core were used. The permeabilities, porosities, formation factors and pore size distributions by the mercury injection method were determined. These data were combined in a formula due to Burdine, Gournay and Reichertz (ibid.). This formula is virtually identical to Equation (5) except that flow through circular capillaries is assumed as a model and the apparent pore size distribution of the capillaries is obtained from mercury injection data instead of an air-water capillary pressure desaturation curve. This formula was written in the form

$$K = \frac{126.6\,\phi\,\overline{r^2}}{(F\phi)^n} \cdot \qquad (7)$$

The quantity $(F\phi)^n$ was written as the tortuosity term

* In the Cornell-Katz model the product $\phi(L/L_e) \cdot L_e = \phi L$ is the actual pore volume of a length L of porous medium of unit area. In the Kozeny-Carman model the analogous product is ϕL_e which is greater than the pore volume. This emphasizes, perhaps, that L_e in the Kozeny-Carman theory is a purely mathematical quantity.

necessary. The object was to determine the value of the exponent n. Permeabilities calculated from Equation (7) were plotted against those measured. A least squares fit of the data gave the value of the tortuosity term as 0.459 $(F\phi)^{1.95}$. The agreement between calculated and experimental values is shown in Figure 1. The least squares quantity may be compared with that expected from Equation (6), i.e., $(F\phi)^2$.

The agreement between the theoretical exponent 2.0 and the measured one, 1.95, is most satisfactory; but what is the significance of the constant 0.459? The constant has been attributed[13] to the original assumption in Equation (7) of circular pores and the probable use of incorrect values for the contact angle between mercury and rock surfaces and the mercury interfacial tension. Further reflection indicates that, although these factors are probably operative, they are not necessarily sufficient in magnitude to account for the constant 0.459. For noncircular pores a shape factor of about 2.5 is not unreasonable although values as large as 3.0 are possible.[5] Taking 2.5 as a plausible figure instead of the 2.0 assumed in Equation (7) is equivalent to increasing 0.459 by the ratio 2.5/2.0, i.e., to 0.575. Thus the numerator of Equation (7) should be increased by the factor 1/0.575 or by 1.74. If the factor 1.74 is attributable solely to a systematic error in the assumed value of $\gamma \cos \theta$ in the basic formula for determining capillary radius from pressure data, i.e.,

$$r = \frac{-2\gamma \cos \theta}{P_c}, \qquad (8)$$

then $\gamma \cos \theta$ is in error by $(1.74)^{1/2}$ or 1.315. The value of $\gamma \cos \theta$ assumed by Faris et al[12] is presumably the same as that used by Burdine et al. From data given in the latter paper, this value appears to be 373.83 dynes/cm. If this figure is systematically incorrect the true value for $\gamma \cos \theta$ would have to be increased by the factor 1.315, i.e., to 488 dynes/cm. Brown[14] gives 368 dynes/cm. as the best presumptive estimate of $\gamma \cos \theta$. However, when mercury injection capillary pressure curves are compared with air-water capillary desaturation curves, Brown's data indicate much higher figures for $\gamma \cos \theta$ for mercury. These range from 378 to 589 dynes/cm. *if it can be assumed that* $\gamma \cos \theta$ *for air-water is in every case 70 dynes/cm.* Brown himself appeared to believe that $\gamma \cos \theta$ for water varied but Purcell in a discussion of Brown's paper was inclined to view changes in $\gamma \cos \theta$ for mercury as being more probable. Taking Purcell's view as one extreme, it may be noted that Brown's data indicate that, on the average, $\gamma \cos \theta$ is 448 dynes/cm. in limestones and 504 dynes/cm. in sandstones. The average is 476 dynes/cm., a figure surprisingly close to the 488 dynes/cm. deduced by analysis of the data of Faris et al.

It is difficult to see how this apparent agreement can be anything but accidental. If the interfacial tension of mercury is 440 dynes/cm., this must be a maximum; any contamination will lower the figure. The maximum value of $\cos \theta$ for a contact angle of 180° is unity. Thus the maximum possible value of $\gamma \cos \theta$ cannot exceed 440 dynes/cm.; almost certainly it is less. Nonetheless it appears that the use of electrical data in the form of $(F\phi)^2$ gives a good approximation to the hydraulic tortuosity required in the model assumed. It would seem also that rather good agreement between measured permeabilities and calculated ones can be obtained by the use of Equation (7) if

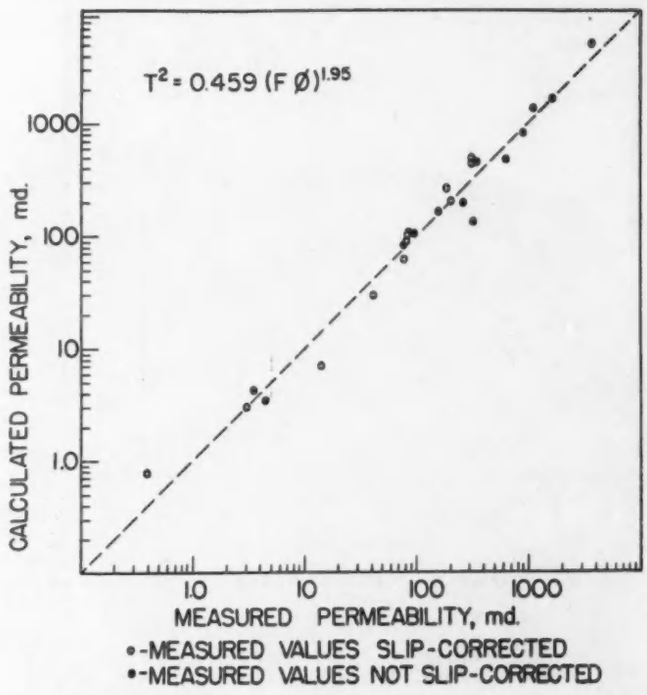

FIGURE 1—Comparison of calculated and measured values of gas permeability. Data of Faris et al. Ref. (12)

the value of $\gamma \cos \theta$ for mercury in a rock is assumed to be the fictitious figure of 488 dynes/cm.

These statements are of pragmatic interest. Since the value of 488 dynes/cm. for mercury in rocks is probably fictitious, what is the consequence of using 368 dynes/cm.? If the latter figure is indeed that applicable, then a constant whose value is about 1.74 has been omitted from Equations (6) and (7). Such a constant might be a numerical representation of the average differences between electrical and fluid flow in natural porous media, e.g., the flow of electrical current from a pore depends in large measure only on the total area available. Under similar circumstances the flow of fluid depends not only on the total area but the manner in which the area is subdivided, i.e., whether there is one large connection or several smaller ones.

Further experiments are required to check both Equations (6) and (7) before a definitive conclusion can be reached.

From the oil industry standpoint the calculation of single phase permeabilities is largely of academic interest. Hence the insufficiency of data already noted. However, the calculation of multiphase or relative permeabilities is far more important (because the experimental measurement of these quantities is difficult). We shall turn, therefore, to a consideration of the relative permeability problem and its relationship to single phase permeability.

Relative Permeability Equations. Equation (6) may be applied to the calculation of relative permeabilities if modern views concerning the nature of multiphase flow are adopted. These views may be concisely summarized as follows. When a wetting and a nonwetting phase flow together in a porous medium, each follows separate and distinct filamentary paths. That is, pores from the smallest up to a certain size (the size depending upon the rela-

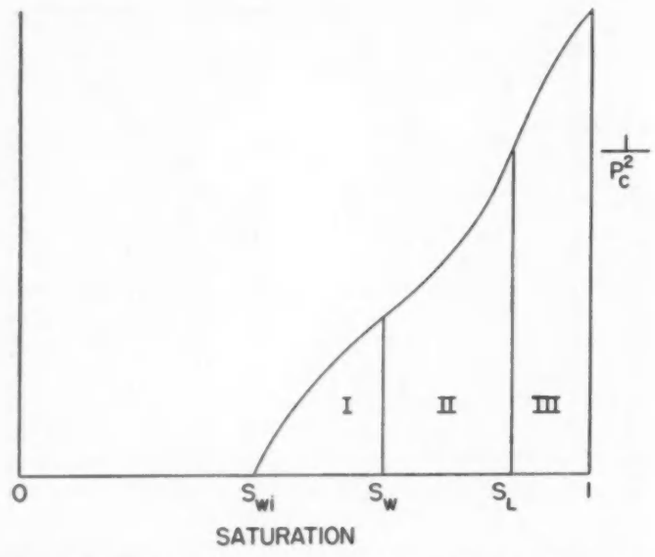

FIGURE 2—Plot of (capillary pressure)$^{-2}$ against saturation.

tive quantities of the two phases present) are available only for flow of the wetting phase and larger pores only for flow of the nonwetting phase. If three phases are present, a wetting liquid, a nonwetting liquid and a gas, similar principles apply. The wetting phase occupies and flows through small pores, the nonwetting liquid phase through larger pores and the gas through larger pores yet.

While the foregoing appears to be true, it is incomplete. Flow patterns are complicated by hysteretic phenomena, i.e., the stability of the flow regimes is dependent upon the manner in which particular saturations of the phases present are obtained. In this discussion it will be assumed that media are initially saturated with a wetting phase and that the liquid nonwetting phase is then introduced thereby decreasing the wetting phase saturation. Similarly, when gas is also present it is assumed that the gas is introduced into a medium containing wetting and nonwetting liquids and that its introduction decreases the nonwetting liquid saturation. A further complication is that pores which are available for flow of nonwetting phases actually contain the wetting phase in a pendular or immobile position. Expressed otherwise, it is possible to have a wetting and nonwetting phase simultaneously present in the medium and yet have the wetting phase completely immobile.

The effect of these considerations when applied to Equation (6) is reasonably straightforward. Each fluid phase may be considered as independent and moving in a porous medium with a pore size distribution defined by the pores through which that phase is able to flow. Hence the expression for the relative permeability of the wetting phase may be written

$$k_{rw} = \frac{(L_e)^2}{(L_e)_{sw}^2} \frac{\int_0^{S_w} dS_w/P_c^2}{\int_0^{1.0} dS_w/P_c^2} \qquad (9)$$

That of the nonwetting liquid phase is

$$k_{ro} = \frac{(L_e)^2}{(L_e)_o^2} \frac{\int_{S_w}^{S_L} dS_w/P_c^2}{\int_0^{1.0} dS_w/P_c^2} \qquad (10)$$

That of the gas phase is

$$k_{rg} = \frac{(L_e)^2}{(L_e)_g^2} \frac{\int_{S_L}^{1.0} dS_w/P_c^2}{\int_0^1 dS_w/P_c^2} \qquad (11)$$

The significance of the integral expression is shown as the areas I, II and III, respectively in Figure 2. The ratios of apparent lengths are the tortuosities of the phases by comparison with the tortuosity of the medium when fully saturated with a single phase. It is assumed in all cases that the shape factor 2.5 cancels, i.e., that pore shape and pore size are unrelated.

The electrical method of estimating tortuosities was applied by Wyllie and Spangler to the case of two phase relative permeability. The ratio of formation factors (F_e/F) at wetting phase saturations of S_w and unity is known as the resistivity index I. Hence from Equation (9) and Equation (5)

$$k_{rw} = \frac{1}{I^2 S_w^2} \frac{\int_0^{S_w} dS_w/P_c^2}{\int_0^1 dS_w/P_c^2} \qquad (12)$$

The term S_w^2 in the denominator arises because the tortuosity at a saturation S_w is equal to $(F_e^2 \phi^2 S_w^2)$.

Similarly as noted by Wyllie[15] on the electrical analogy

$$k_{ro} = \frac{1}{I_n^2 (1 - S_w)^2} \frac{\int_{S_w}^1 dS_w/P_c^2}{\int_0^1 dS_w/P_c^2} \qquad (13)$$

Here I_n is the nonwetting phase resistivity index.

Equation (12), as was pointed out in the original discussion,[8] can be considered to be only approximate. Quite apart from uncertainty regarding the equivalence of electrical and hydraulic tortuosities, when the wetting phase saturation in a porous medium is not unity a further complication is experimentally evident. The wetting phase hydraulic tortuosity becomes infinite at a finite value of S_w. This value is the so-called irreducible wetting phase saturation S_{wi} (Figure 2). At the same saturation the electrical tortuosity is finite. Physically this is the result of grains covered by thin films of liquid able to conduct electrically. These films are unable to support laminar flow of fluid.

This limitation does not apply to Equation (13). However, there are insufficient data available to assess the usefulness of this equation.

Electrical methods of finding the tortuosity ratios applicable in the calculation of relative permeabilities are, therefore, inherently approximate or untested. In consequence the approach has been to use equations of the form of Equations (9) to (11) and, by comparing the ratios of the integral expressions with experiment, to find tortuosity ratios as a function of saturation. This empirical approach, well exemplified by the work of Burdine[16] and Corey,[17] has proved most fruitful. Another approach has been to refine further the model of the porous medium used to calculate Equations (9) to (11) and thus to arrive at expressions for tortuosity ratios which do not require the electrical analogy. It is this approach which will be considered in Part II.

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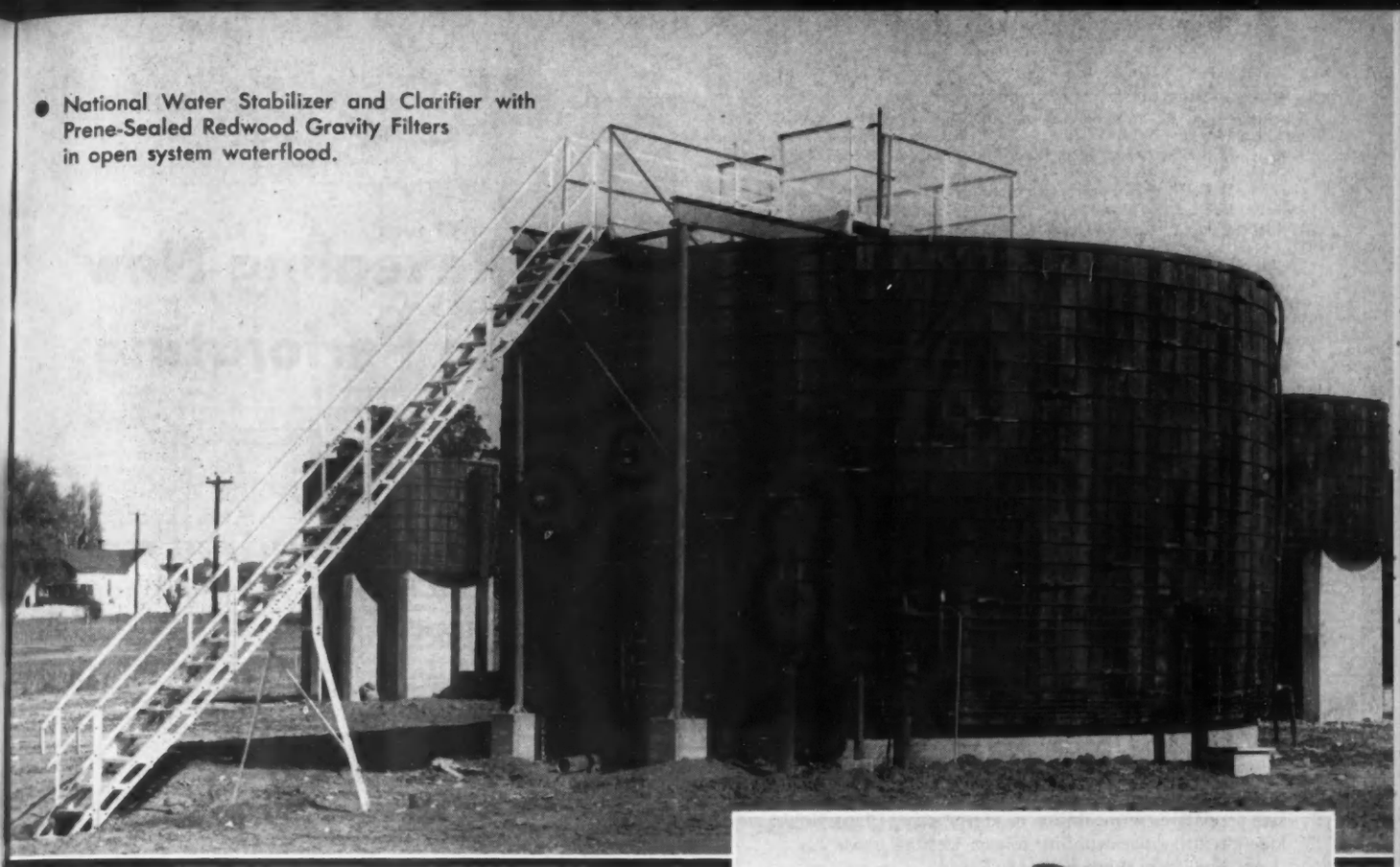

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NOMENCLATURE

A = bulk area of porous medium
F = formation factor (electrical) at 100% saturation
F_e = formation factor at wetting phase saturation S_w
I = resistivity index of wetting phase = F_e/F
I_n = resistivity index of non-wetting phase
K = single phase permeability at 100% saturation
k = Kozeny-Carman constant $\cong 2.5(L_e/L)^2$
k_{rw} = relative permeability to wetting phase liquid
k_{ro} = relative permeability to non-wetting phase liquid
k_{rg} = relative permeability to non-wetting phase gas
k_o = hydraulic shape factor $\cong 2.5$
L = actual length of porous medium
L_e = apparent length of porous medium; or actual length of capillary tube
$(L_e)_w$ = apparent length of that part saturated by wetting phase liquid
$(L_e)_o$ = apparent length of that part saturated by non-wetting phase liquid
$(L_e)_g$ = apparent length of that part saturated by non-wetting phase gas
m = mean hydraulic radius
n = geometrical factor in capillary-probability model
P = pressure gradient = $\Delta P/L$
ΔP = pressure differential
P_c = capillary pressure
Q = quantity of fluid flowing/unit time
R = arbitrary radius, electrical resistance of fluid contained in unit length of model of unit cross-sectional area
R_o = electrical resistivity of conducting fluid
r = radius of capillary tube
$\bar{r}$ = radius of an equivalent tube in capillary-probability model; average radius as defined in Reference (10)
S = surface area per unit bulk volume; saturation as a fraction of pore volume
S_m = minimum non-wetting phase saturation for mobility
S_L = fractional total liquid saturation = $S_w + S_o$
S_o = fractional non-wetting phase liquid saturation
S_w = fractional wetting phase liquid saturation
S_{wi} = fractional immobile ("irreducible") wetting phase saturation
S_w^* = effective wetting phase saturation = $(S_w - S_{wi})/(1 - S_{wi})$
S_o^* = effective non-wetting phase saturation = $(S_o)/(1 - S_{wi})$
u = macroscopic or approach velocity
u_e = average velocity in pores of porous medium or actual average velocity in a capillary tube
$\alpha(r)$ = distribution function governing capillary radii, i.e., $\alpha(r)dr$ capillaries have radii between r and $r + dr$
β = geometrical factor in capillary-probability model
γ = interfacial tension
ϕ = fractional porosity
ϕ^* = effective porosity = $\phi(1 - S_{wi})$
θ = contact angle liquid-solid
μ = viscosity

TO BE CONTINUED

Tests Revealing New Data on Perforating

Experiments in West Coast permeability lab will help engineers choose proper techniques.

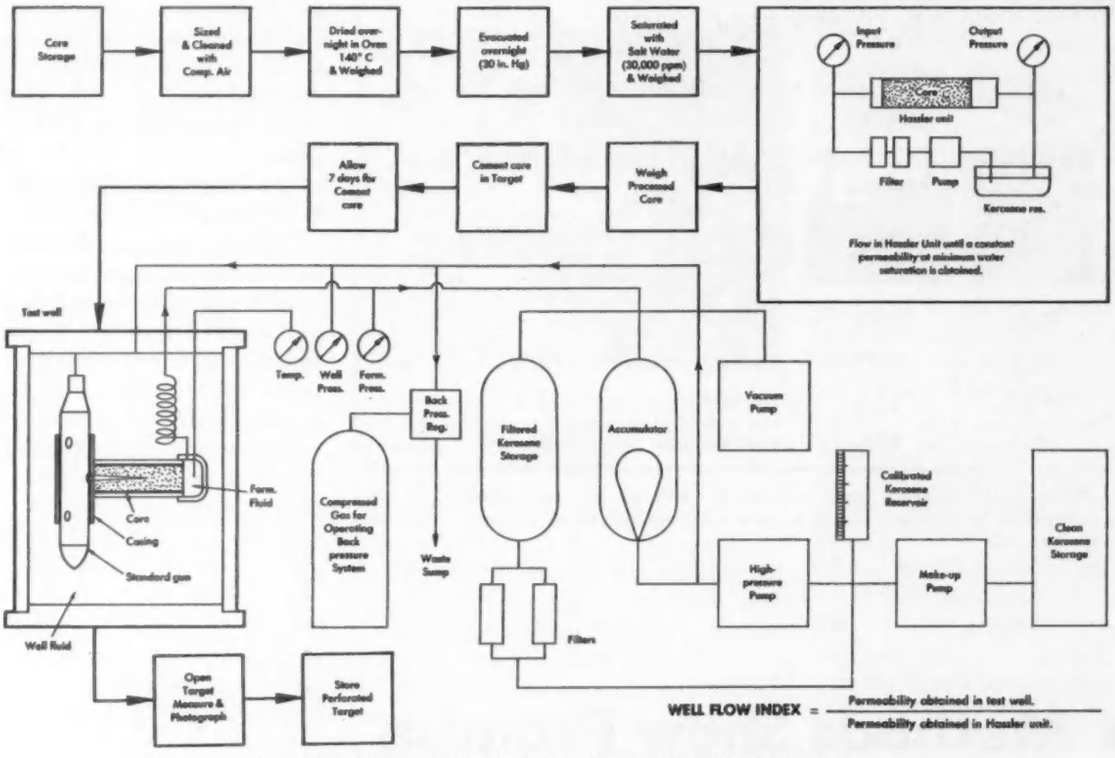
By Gilbert M. Wilson, WORLD OIL Staff

MORE PRECISE and highly interesting answers to the question of what happens to the formation when shot by bullet or shaped charge perforators are being revealed in special perforating tests being conducted under simulated well conditions at Lane-Wells Company's new Permeability Laboratory in Los Angeles. From these tests, which have been conducted over the past year, data are being developed which will provide a more accurate method of determining the type of perforation most likely to produce the maximum amount of oil under any given set of well conditions.

The testing process consists essentially of conditioning a large diameter (3 9/16-inch) Berea sandstone core to specific hydrocarbon and salt water saturation and, under elevated temperature and pressure simulating well conditions, the permeability is determined. The test core then is shot in a horizontal position—an important factor in itself—and, still under simulated well conditions, again is tested to determine its permeability. The ratio of permeability before and after perforation is the "Well Flow Index," a relationship that is destined to become an increasingly valuable tool in determining the optimum type of perforator and technique for any given formation.

During the first year's operation of the laboratory, a Well Flow Index has been established for every known size and type of perforator available, each being tested at pressures and temperatures exceeding those encountered in the field. Elaborate controls enable laboratory engineers to regulate pressures and temperatures over wide differentials, simulating conditions likely to be encountered when a well is perforated. Typical of the pressures that might be used in testing a core would be 1,000 psi in the "well" bore and 1,200 psi in the "formation" to be shot. On other tests, these pressures might be reversed to observe the opposite effect when the well is perforated.

Upon shooting a test specimen and after permeability flow tests have been completed, the core is removed and



PERMEABILITY FLOW-LAB SCHEMATIC DIAGRAM

sawed in half longitudinally to observe the size and shape of the hole, position and quantity of debris, if any, left in the hole, the degree of cracking of the surrounding formation, mudding-off or blocking of surrounding formation, if any, and other conditions of the hole.

The objective of the tests, of course, is to develop charges and perforating techniques which, when used under the proper conditions, will yield well flow indices greater than one, indicating that permeability after shooting was greater than that which existed before.

Even at this relatively early stage, it appears certain that some previously held opinions as to what happens when the formation is perforated, will have to be revised, and techniques changed accordingly. It seems probable, for example, that there will be a trend toward an attempt to develop a single massive fracture in the best part of the formation. There is belief, too, that the number of shots per foot may be scaled downward. Certain types of perforators, it is believed, may be more effective when used in conjunction with subsequent treatments such as fracing or acidizing. Certain beneficial results are obtained in some instances when *both* bullet and shaped charge perforating is done in the same formation.

Evidence so far gained points toward the need for further research into the shape and size of bullets and shaped charges, along with the quantity and type of propellants or explosives used. This can lead to more effective fracturing of the formation and, in turn, better wells. This will lead, too, toward more effective treatment of the less permeable sections of the pay zone and subsequent improvement of their productivity.

A new field of study, that of spotting non-plugging agents opposite the formation during shooting, undoubtedly will evolve and will be guided by the results of the new laboratory and the techniques being developed. For example, it has been determined from studies conducted in laboratory specimens that colloidal particles often are injected into the formation when shot in the presence of mud, thus materially reducing the flow characteristics. Non-plugging agents currently being used or under development, include salt water, oil, chemicals and even carbon tetrachloride.

Although the mechanics of spotting such agents at the precise place needed, probably using drill pipe or bailer, still have not been entirely perfected, the use of such agents holds great promise. In permanent well completion work, for example, the advantages would be great.

Aside from the effects upon the formation which now can be studied, the new laboratory enables engineers to quickly evaluate new types and quantities of charges or propellants. Very high bottom-hole temperatures, encountered in some fields, have somewhat restricted the use of certain types of bullet propellants, whereas shaped charges have been found to have a much higher range of temperature limitations. Merely by simulating these extremes in the laboratory, various new types of explosives, containers and powders can be checked out quickly and effectively.

This is the only laboratory in the U. S. in which cores are perforated in a horizontal position, thus avoiding the problem of having debris falling in the "bottom" of the hole as would be the case in a vertically mounted core. New facilities currently are being built that will enable simultaneous firing of more than one shot. Such a test unit will permit studying such things as interference and effects of the following shot upon the previous one; also the study of what hydrafracing effect, if any, the following shot will have upon the first hole.

The foregoing points, of necessity touched upon only briefly, serve to point up the high promise held for the laboratory and the techniques employed, all aimed at improving perforating effectiveness and subsequent improvement in well production.

—The End

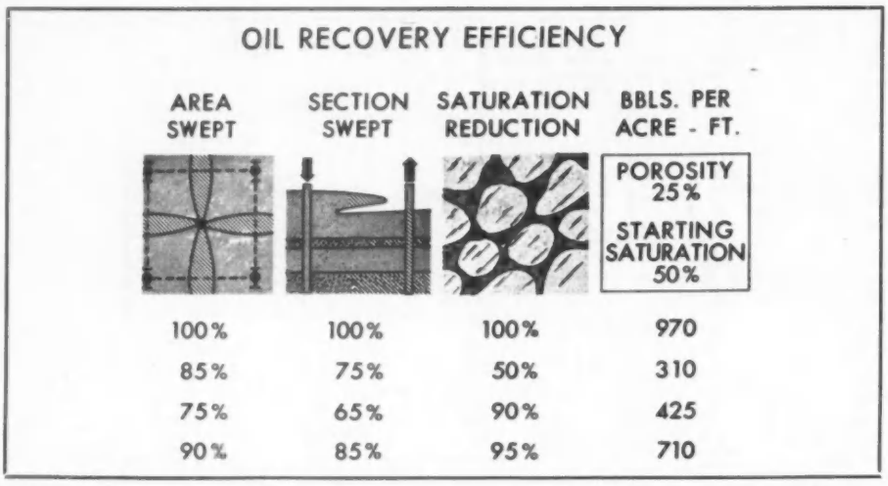


FIGURE 1—Recoverable reserves from a reservoir with 25 percent porosity, 50 percent starting saturation for various sweep, section efficiencies and saturation reductions.

New Methods Show Promise Of Increasing Oil Recovery

Gas driven solvent bank and enriched gas injection processes have proven successful in field trials.

By Charles D. Russell
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THERE ARE no cure-alls for increasing the recoverable oil reserves of the U. S., but solvent extraction and miscible fluid displacement in general show great promise. There has been considerable advancement with respect to basic laboratory and theoretical work on solvent extraction processes. Considerable costly field testing is needed to determine the circumstances in the field where solvent extraction processes work most advantageously. This field of reservoir engineering is not as yet firmly established but is in the process of evolution. Conservation minded individuals must by their positive and forward looking actions insure that the necessary research and engineering development is undertaken in the field of solvents as well as other oil recovery processes to assure proper development of the nation's oil reserves.

There is considerable talk at this time about fossil fuels, solar energy and nuclear energy. One of the most responsible views is that for the immediate future, there is no need to worry about our coal and oil reserves. But by the end of the century, we must be prepared to pay considerably higher prices for these fuels.[1] It is forecast that the energy consumption of the Free World in the year 1975 will be almost twice that of 1955 and that roughly 45 percent of this energy must be supplied by petroleum. This figure compares with slightly over 5 percent of that anticipated to be supplied by nuclear energy. For a long while into the future it is probable that no matter how inexpensive nuclear fuels become, oil and gasoline will retain a most important role in transportation. There are some applications of energy where no substitute for oil fuel is in sight. This emphasizes the importance of conservation practices with respect to the oil supplies of our nation.

The oil industry is periodically forced to review its potential, i.e., its ability to replace current production and supply additional quantities of oil to meet future requirements.[2] Research people are faced with a great challenge to provide new oil recovery methods to supplement geological and geophysical efforts to replace the 3 billion barrels of crude oil and natural gas liquids consumed annually. Complete success in the development of new oil recovery methods could mean hundreds of billions of barrels of additional oil in the U. S. alone. Partial success would contribute very significant added recoverable reserves. Basic research is necessary and oil management financing this research must not give up too easily. This area of research is a gamble but the odds are not prohibitive and if it pays off, high financial return can be realized.

The recovery factor is higher in some fields than in others; but, in general, for every barrel brought to the surface, an average of two barrels is left behind. There are two broad reasons for this obvious inefficiency:

1. Due to heterogeneities in the reservoir and the channeling of fluids, some oil is bypassed.
2. Even in regions of the reservoir sand from which oil drainage takes place, unrecoverable oil is retained by capillary forces.

From a scientific standpoint it is possible to work on ways of improving volumetric coverage in the reservoir and also on methods that reduce the effects of capillarity, or completely eliminate it. This can best be illustrated by Figure 1, entirely schematic. If the reservoir has 25 percent porosity and a starting oil saturation of 50 percent of the pore volume after normal primary depletion, the reserves are 970 barrels of oil per acre-foot. All of this oil could be recovered if the area swept, the section swept and the saturation reduction were 100 percent. For some water-floods, the saturation within the pores might be reduced by 50 percent. With 85 percent sweep efficiency and 75 percent section

efficiency, the oil recovery would be 310 barrels per acre-foot. Even if a higher reduction of saturation in the pores could be expected, i.e. possibly 90 percent, poor sweep and section efficiencies could prevent the process from yielding more than one-half of the oil. It is necessary, therefore, to look for a process, or a combination of processes that gives a high reduction of saturation and at the same time high areal and section sweep. Various new methods have been tried.[3] This discussion deals principally with the single subject of solvent extraction as a means for promoting higher recovery of oil in gas-drive operations.

An obvious way to get oil out of a permeable material is to wash or extract it with a solvent that mixes with the oil. It is an established fact in the laboratory that all of the oil can be extracted from a reservoir rock if enough propane or LPG is flushed through the reservoir. In fact, this method was suggested as an oil production technique in the 1930's by Uren.[4] Further reference to the literature of recent years shows that considerable technical effort has been expended on this approach.[5 through 31] LPG is fairly abundant and is easily recoverable from crude oil. It would, in general, appear to be a very desirable solvent for recovering crude. However, it is uneconomical to trade a barrel of LPG for a like volume of crude oil. This fact leads to at least two approaches, both of which use only a small quantity of LPG. These may be called the *gas-driven solvent bank proccess* and *enriched gas injection.* Both of these techniques are potentially capable of recovering much more than one barrel of oil per barrel of LPG. Moreover, the solvent should be recoverable for sale or re-use.

There are a number of other processes that have been covered in the literature, all of which rely on the solvent extraction principle; i.e. the displacement of oil is accomplished by a bank of intermediate hydrocarbons that is driven in turn by gas.[28] They differ somewhat in nomenclature and also in the manner in which the intermediate hydrocarbons are formed into a bank. Some of the techniques rely on complete miscibility of the flowing fluids in the reservoir. Others depend only on partial miscibility and in reality should be classified as immiscible displacement processes. In this latter case,

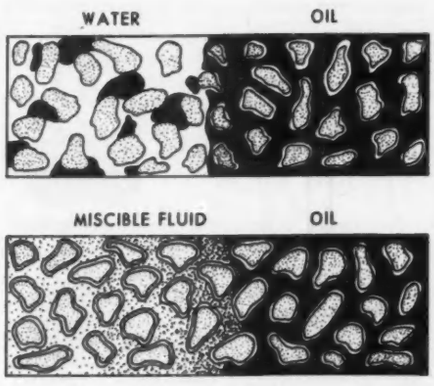

FIGURE 2—Water-flooding (top) and solvent extraction (bottom) illustrate the mechanism of immiscible and miscible fluid displacement, respectively.

the improved oil recovery can be accounted for by the vaporization and condensation effects which occur in the reservoir. The improvement results from the swelling and viscosity reduction of the crude oil which is displaced. The two methods mentioned were chosen for discussion because they represent exploitation techniques that have had some measure of success in field trials.

In order to understand the mechanism of solvent extraction, it might be fruitful to compare this process with water-flooding. A schematic attempt to show this is given in Figure 2. Each of these diagrams can be thought of as a micro cross-section of reservoir rock. Flow is from left to right with an input well far off to the left and a production well to the right. For the case of water-flooding, as shown in the upper diagram, water pushes the oil out of the way in a reasonably piston-like manner. Behind the front, isolated pockets of oil are left behind. This is an example of *immiscible fluid displacement* in which capillary forces cause retention of the oil in the pores

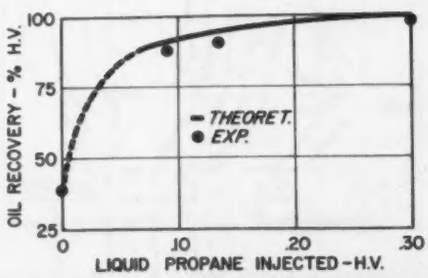

FIGURE 3—Experimental vs. theoretical results for the gas driven solvent bank process using propane. Note that excellent agreement was obtained with experimental results.

of the rock. With solvent extraction, as shown in the bottom diagram, a *miscible fluid displacement* takes place. The displacement proceeds as in the water-flood except that a sharp discontinuity does not exist between the two fluids. There is no interface similar to that found in an immiscible fluid displacement. Instead, there is a transition zone, or a region where the solvent and the oil mix. Aronofsky treats this diffusional problem very nicely with his phenomenological theory of the mixing and diffusion process for the flow in a porous medium of two miscible liquids of equal density and viscosity.[25] The miscible displacement process is rate sensitive. The flow rate must be slow enough to allow the solvent to mix with the oil so that the oil can be extracted efficiently. Also, when banks or slugs of solvents are used, the rate must be fast enough so that the bank will not spread out too far by diffusion and thus be destroyed. Generally speaking, practical oil field rates are bracketed within this range.

Gas-Driven Solvent Bank Process. As previously mentioned, it is uneconomical to trade a barrel of propane or LPG for a barrel of oil. It is of course possible to remove part of this economic disadvantage by recovering most of the solvent and using it again. However, generally this would require an abnormally large supply of LPG, require its use for a long period of time in the reservoir and require large expenditures for processing equipment. The best apparent way to improve the economics is to use the minimum possible amount of LPG in the process. One way to accomplish this is to inject a small bank of LPG at the input wells and drive it by gas through the reservoir to the producing wells.

Success was achieved with this process in laboratory scale models. It was observed that excellent oil recoveries were obtained depending upon the size of the LPG bank used. See Figure 3. In this plot the oil recovery is expressed in percent of a hydrocarbon volume; the bank (or slug) size is expressed as the fraction of a hydrocarbon volume. For a linear, homogeneous laboratory model, the oil recovery approaches 100 percent H.V. when the bank of propane approaches 0.30 H.V. With a bank size of 0.15 H.V., the oil recovery is in excess of

90 percent H.V. or about twice that obtained in the same model by water-flooding. The theoretical picture for this process is reasonably well-defined at the present time and has been treated rather completely by Johnson and Welge.[17] This discussion will not go into this theory in detail, but it it sufficient to point out that excellent agreement has been obtained with the experimental results. This is shown also in Figure 3 when the curve is compared with the experimental points. The utility of this theoretical approach is, of course, obvious. Calculative predictions for linear systems can be made in a reasonable length of time, either with medium-speed computing machinery or hand calculators. It is also possible, for example, to arrive at oil recovery efficiency without resorting to long and costly experiments. The effect of changing such variables as pressure, temperature and solvent composition can also be readily explored.

Petroleum technologists also have a reasonably complete mechanistic knowledge of miscible fluid displacement in general. Lacey, Draper and Binder presented a complete discussion of this subject.[16] One of the most important observations made was that a distinct difference was found between vertical and horizontal solvent floods. Because of the influence of gravity, flooding in the vertical direction (solvent injected at the top) is more efficient than in a horizontal injection. This effect is illustrated in Figure 4, which shows the vertical flood recovering 10 percent more oil. This situation could be more pronounced in the field where it is possible that poor volumetric coverage (or low conformance) may have an adverse effect on the horizontal flood and perhaps very little effect on the vertical. This points up the beauty of crestal injection for solvent processes. It may turn out to be a fact that for the most efficient operation of solvent processes involving adverse mobility ratios, production people may prefer fields with significant dip to apply this technique. Other approaches pointed at obtaining higher conformance in horizontal pools are being tried, for example, simultaneous water and gas injection.[22]

Another important point is that many reservoirs are watered out before they become possible candidates for solvent extraction. Talasch and Crawford state that in laboratory models substantially all of the oil remaining after water-flooding can be recovered by subsequent flooding with petroleum solvent.[21] By fractionation and recirculation of the produced effluent, it may be possible to reduce the solvent requirements by a factor of two or three. However, this may not be enough to make the process financially attractive. At the Carter Laboratory, researchers have applied the gas-driven solvent bank process to watered-out models. It is found that of the 39 percent P. V. oil remaining after a water-flood, approximately one-half of it was removed as a result of the solvent extraction process. Although it is generally not practical, it would be better not to water-flood prior to using solvent extraction to recover oil from a reservoir. On the other hand, there are many likely candidates for solvent flooding among pools already watered-out. It might still prove attractive financially to apply the gas-driven solvent bank process to some of these pools.

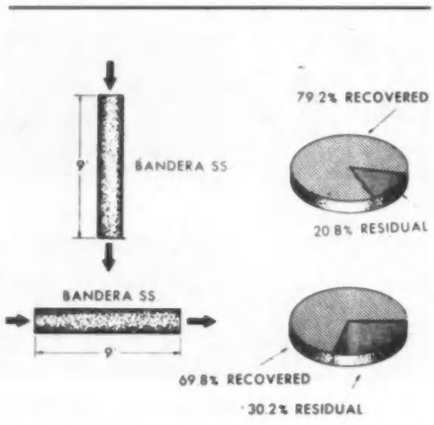

FIGURE 4—Because of the influence of gravity, flooding in the vertical direction (solvent injected at the top) is more efficient than in a horizontal injection. Note the vertical flood illustrated recovered 10 percent more oil than the horizontal flood.

C-2 Block Field Test. As a result of encouraging laboratory results, plans were initiated in 1952 to test the gas-driven propane bank process at Carter's C-2 Block leases in Seminole County, Oklahoma. A report of this operation has been given in complete detail by Jenks, Campbell and Binder.[14,15] The coverage presented here is to bring this picture up to date.

The test is being run in the Booch sand which is a bar-shaped producing horizon occurring at a depth of 3500 feet. The total reservoir thickness varies from 12 to 32 feet. The porosity averages 18 percent; the air permeability varies from 1 to 100 millidarcies, the average being 30 millidarcies; and the connate water averages 35 percent. The natural depletion mechanism which operated in the reservoir is thought to be solution gas drive. No significant water was produced during primary depletion.

Figure 5 is a map of the C-2 test area. The four primary producing wells are the Wisner 1, the Sanford 1 and 2 and the Hodges 1. Several additional wells were drilled: the Wisner G-1 and Sanford G-1 for propane and gas injection; the Wisner 2, a new production well; the Wisner W-1 and the Sanford W-1 as water injection wells so that a water barrier could be established across the northern end of the test area. This water barrier was considered necessary to minimize the loss of hydrocarbons from the test area, defined as that portion of the reservoir falling between the dashed lines on the map. Although not related directly to the test, other wells have been drilled in the area; some are indicated also in Figure 5. There are effectively eight additional producing wells outside of the test area that are being observed regularly for possible test influence.

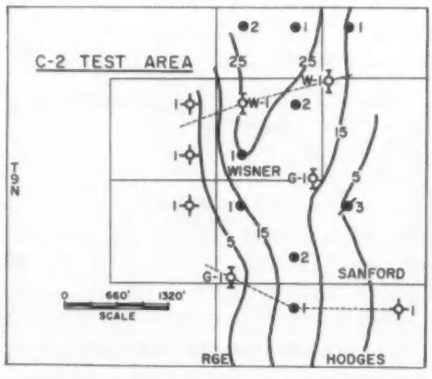

FIGURE 5—The C-2 Block field test in which 6 million gallons of propane was injected and driven with 569 MMcfg during a three year period.

After work-over operations and preliminary data gathering were completed, the reservoir was repressured

to 250 psia by injecting approximately 54 million cubic feet of gas. This was necesary in order to keep the propane in a liquid state at the reservoir temperature of 120° F. Six million gallons of propane were then injected, two-thirds at the Wisner G-1 and the rest at the Sanford G-1. This injection of the propane bank was completed on October, 1953. In early March, 1954, gas-drive was started to propel the propane banks through the reservoir toward the production wells. To October, 1957, a total of 569 million cubic feet of gas had been injected, 99 million cubic feet at the Sanford G-1 and 470 million cubic feet at the Wisner G-1. These figures do not take into account the gas used for the original repressuring operation.

The daily production rate and the gas-oil ratio plotted versus time are shown in Figure 6. The daily production rate increased from about 13 barrels of oil per day to over 200 barrels of oil per day early in 1954, and has decreased steadily during the four-year test period to a present value of 34 barrels of oil per day. State allowable proration restricted production for about a year following the initial response. The total oil production to October, 1957, was 140,000 barrels. This parallels a gas production of 535 million cubic feet and a propane production of 71,400 barrels, or 50 percent of the injected volume. The general shape of the GOR curve as a function of cumulative oil production is shown in Figure 7.

Test interpretation is a complicated proposition and it is difficult to do this rigorously during the course of the test. At the moment, several things are being done to help with this interpretation. For example, plans are underway to drill several core holes within the test area in an attempt to evaluate residual oil after flooding and to obtain data on section and areal sweep, which is effectively a measure of conformance. In the final phases of the test operation, the depressuring program should give valuable information on reservoir volume. Also, for about a year a radioactive tracing program has been underway which should show the degree of channeling and the evaluation of conformance.

In the tracing program, four curies of krypton 85 were injected into the Wisner G-1 and two curies of tritiated

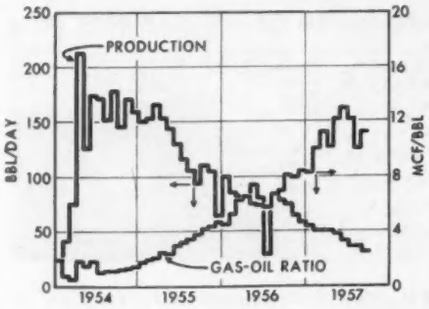

FIGURE 6—Total oil production recovered in the C-2 Block field test has been 140,000 barrels over a three-year period, with gas production of 535 MMcf and 71,400 barrels of propane, 50 percent of the injected volume.

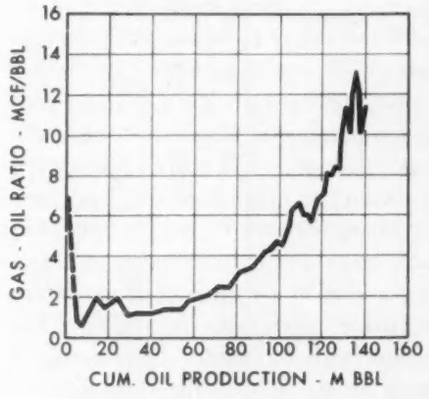

FIGURE 7—General shape of the GOR curve as a function of cumulative oil production for the C-2 Block field test.

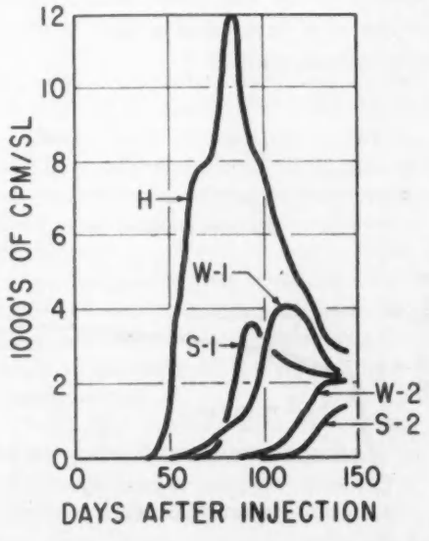

FIGURE 8—Curves obtained from C-2 test tracer data can be used to determine the degree of channeling and various factors which affect conformance. The number of counts per minute per liter of produced gas is plotted as a function of time.

methane into the Sanford G-1. Periodic samples are taken at the producing wells and an accurate low-level radioactive count is made on these samples. Figure 8 illustrates the type of data obtained at several of the wells. The number of counts per minute per liter of produced gas is plotted as a function of time. Generally, shortly after the radioactive material appears at the producing wells, the radioactive count increases and the curve passes through a maximum and then falls off after the bank of radioactivity is past. The shape of the curve and the area under the curve aids the engineer to determine the degree of channeling and various factors which affect conformance. This radioactive tracing program is one of the first real quantitative efforts of this type in the producing end of the oil industry. It is another example of how the producer takes advantage of the latest technological advances to solve difficult problems.

There are several things that can be mentioned even now from the standpoint of test interpretation. At least two barrels of oil have been produced for every barrel of propane used effectively in the process. Present indications are that severe channeling did not take place. Finally, it has been shown that substantial quantities of oil can be produced by the gas-driven solvent bank process at modest propane-oil and gas-oil ratios. On a research basis, it is felt that the moderate success achieved in this test should continue to spark industry interest. Moreover, it is evident that many other such ventures should be attempted until the gas-driven solvent bank technique, or various modifications thereof, will become a proven economical method of obtaining more complete oil recovery.

Enriched Gas Injection. Another approach which leads to the minimizing of the amount of LPG needed for solvent extraction is called enriched gas injection; sometimes it is termed wet gas injection or condensing gas drive. In this technique substantial quantities of LPG are added directly to the gas stream and this enriched gas is injected as a driving fluid. Industry effort in this field is high. Several companies are engaged not only in laboratory and theoretical studies of this approach but are also running

active field tests. Figure 9 illustrates how this process works. This represents a reservoir cross-section in a rough manner with saturations plotted versus distance. Flow is from left to right. The LPG in the gas stream condenses and dissolves in the crude oil. This reduces the viscosity and swells the oil in this region. Thus, an oil bank rich in LPG is built up ahead of the gas front very similar to the solvent bank injected in the gas-driven solvent bank process. Such a displacement can be entirely within the miscible region, or only partially, depending upon the physical and chemical characteristics of the hydrocarbons present in the reservoir.

Hall, Merliss, and Ewing have covered the subject, gaseous injection of hydrocarbons, very completely.[28] It is sufficient to state here that high pressure gas-drive, solvent bank flooding, and enriched gas injection are all related. The pressure-volume-temperature (PVT) behavior of the hydrocarbon components present during the gas-drive operation determines whether the process is a miscible or an immiscible fluid displacement. It can generally be considered to be the most efficient way of conducting the gas-drive when conditions of complete miscibility prevail. However, considerable benefit can be derived in immiscible cases because of swelling and lowered viscosity of the oil as well as the vaporization effects.

It is interesting to look briefly at some laboratory results on enriched gas injection. A set of data is shown in Figure 10. This has to do specifically with the effect of the amount of solvent contained in the driving gas on the oil recovery versus throughput curve. In this particular case a "live-oil" is used. Methane and propane are dissolved in an odorless paraffinic solvent in the proportions shown. Three gas-drive runs were made: (1) dry gas, (2) equilibrium gas containing only 9.7 percent propane, and (3) rich gas containing 18 percent propane. As shown by the lower curves, which nearly coincide, driving the system with equilibrium gas, containing the 9.7 percent propane gives very little improvement over dry gas for this particular system. In the case of the 18 percent propane gas, the recovery of oil approaches 100 percent at less than three hydrocarbon volumes throughput. This set of results

MECHANISM OF WET GAS INJECTION

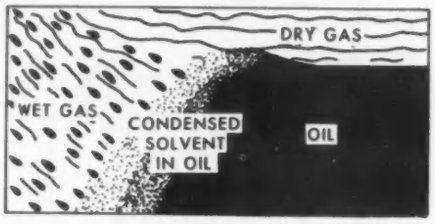

FIGURE 9—Schematic illustration of enriched gas injection.

is important in clarifying one point for engineering applications. Unless there are enough condensible hydrocarbons to give a mixture in excess of the equilibrium gas mixture, it is of no advantage in the producing operation to add the material to the gas injection stream. It would be better, in this instance, to stockpile the LPG and save it for another application of enriched gas injection, for a bank or slug type injection, or immediate sale. Each reservoir system has its own peculiarities and considerable experimental and theoretical study must be made before accurate predictions of reservoir behavior can be made. In general, it may be stated that the three dimensional reservoir problem has not been solved directly but that it can be broken down into three more easily solved components: the areal system, the cross-section and the linear system. By making judicious assumptions, it is possible to tie the three components of the problem into a final three-dimensional solution.[28]

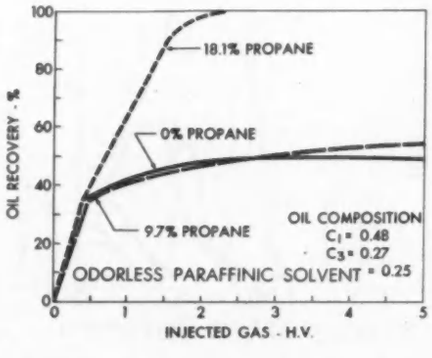

FIGURE 10—Laboratory results of enriched gas injection with three gas runs. It is interesting to note the increased "live-oil" recovery with 18.1 percent propane over the 9.7 percent and dry gas runs for this particular system.

ACKNOWLEDGMENT

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Workover Costs Reduced with Concentric Tubing Tool

The use of ¾-inch tubing as a workover tool resulted in a net savings of $552,155, based on conventional rig costs, on 71 jobs completed by Gulf in the Louisiana Delta.

By R. J. Goeken
Gulf Oil Corporation
Triumph, La.

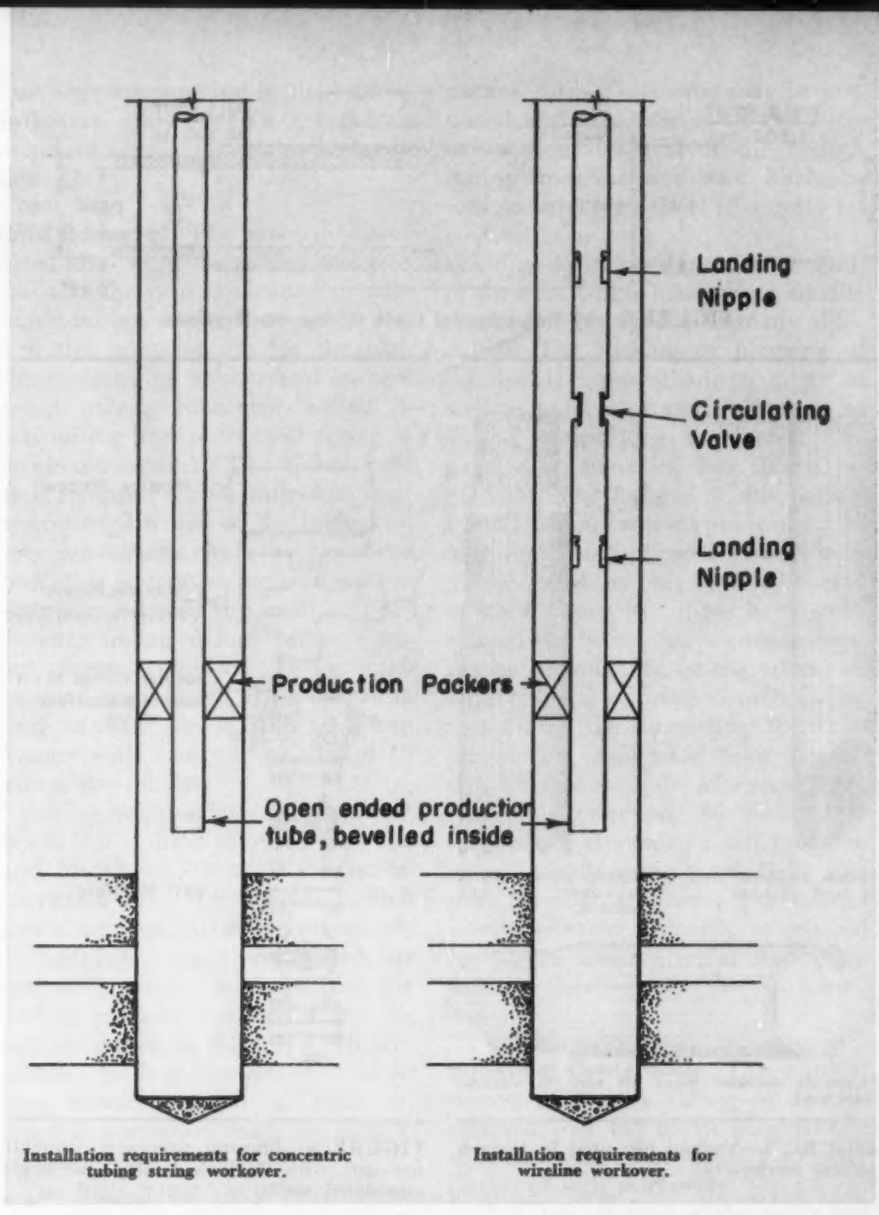


FIGURE 1—Specific tubing requirements of through-tubing workovers.

THE USE of small outside-diameter tubing as a workover tool can become the most practical and cost-saving idea since the advent of permanent-type well completions. During a work period of 18 months, successful operations have included sand removal, squeeze cementing, displacement plug cementing, set-cement removal, sand control, acidizing, and various job combinations. A total of 71 jobs have been completed by Gulf in the over-water fields of the Louisiana delta.

Sand removal was attempted in 58 jobs; only 8 failures were recorded. Fifty percent of successful well clean-outs resulted in restoration of production. A net saving of $438,000, based on conventional rig costs, is ascribed to sand removal. Nine successful plug-backs were completed out of 11 attempts; this resulted in a net saving of $99,773. Two of the successful plugbacks were completed in single-string, dually completed wells and at no time during the workovers were the casing wells closed in or otherwise disturbed.

It is apparent that a tool is available to industry capable of reducing workover costs and of broadening the scope of permanent-type well completions.

Since the introduction of permanent-type well-completion methods in 1950, continuous improvement in wireline techniques and equipment has led to very substantial savings and has resulted in extensive adaptation of this tool in the industry. Wireline workovers have become commonplace, and the proficiency of associated services has progressed to a high degree. Certain job conditions or well characteristics, however, have prevented the successful completion of wireline workovers. Such situations have been met, and successful operations have been effected through the use of small outside-diameter tubing as a workover tool.

The initial work with small outside-diameter tubing was undertaken by Gulf Oil Corporation in the over-water operations of the Louisiana delta and involved simple well-bore cleanouts of produced sand. Continued successes in this type operation prompted extending the tool to other well-workover requirements. The apparent potential of this method of workover was promptly recognized by contractors and outside oil com-

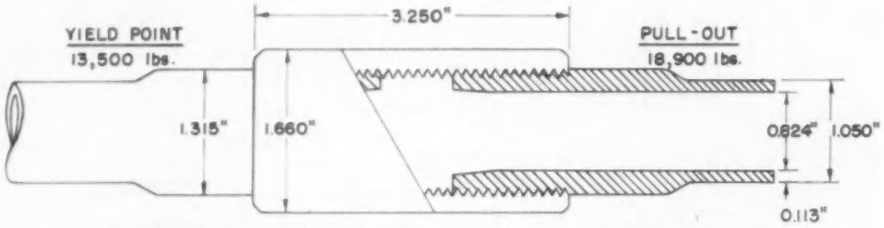
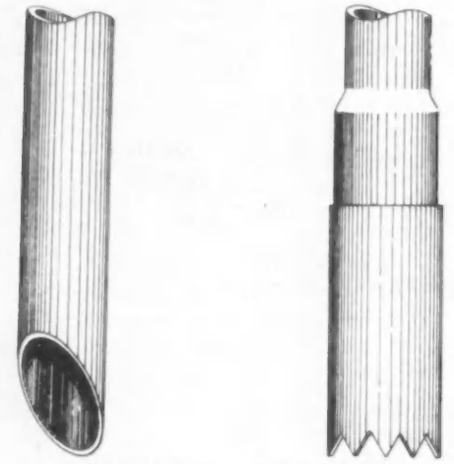


FIGURE 2—¾-inch external upset tubing specifications.



¾-inch muleshoe used in sand washout.

Rotary show utilized in cement and junk removal.

Shopmade diamond point bit used to washout hard sand.

FIGURE 3—Various bits used in ¾-inch tubing workovers.

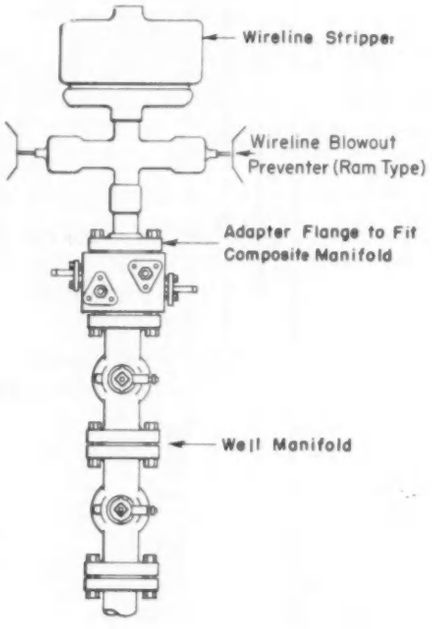


FIGURE 4—Blowout preventer assembly for use with ¾-inch tubing in single completed wells.

panies. Contract units are now available which are suitably equipped for this type work.

Although backed by only 18 months experience, the record of small outside-diameter tubing workovers is impressive and will be presented with a cost comparison of conventional workover rig operations. The equipment requirements, techniques, procedures and economics of this type workover will also be presented.

Well Installations. General tubing requirements for concentric-tubing workovers, as shown in Figure 1, are similar to that for wireline work in that the tubing must be open-ended, full-opening and bottomed above all desirable completion intervals. The specific requirements, however, are much simpler in that the wireline operated circulating device and landing nipples are not a requisite of concentric-tubing work. Exclusion of this equipment as a requirement of permanent-type completion operations would not only cut down installation costs but would also, in some instances, allow limited work in wells not originally equipped for permanent-type completion workovers. In wells with full-opening packers, but with bull-plugged production tubes, the tubing may be made open-ended with a jet or chemical tubing cutter to allow concentric tubing operations.

Equipment Requirements and Tools. The basic equipment essential to concentric-tubing workovers is as follows:

1. A tubing string of sufficient length and clearance to run concentrically within the producing string to the desired depth. All concentric-tubing workovers in Gulf's operations have utilized ¾-inch EUE J-55 tubing as shown in Figure 2. Only four tubing failures have occurred during the past 71 jobs. One failure resulted from parting in the threads, and the others were caused by parting in the tubing body. Thread wear has been severe inasmuch as tubing is run and pulled in singles. The first tubing string was initially received as Class "B" and, after 59 jobs, was replaced. Past service indicates ¾-inch EUE tubing to be quite suitable for work of this type. The various bits used in ¾-inch tubing workovers are shown in Figure 3.

2. Blowout-prevention control must be provided. Blow-out preventer equipment for ¾-inch tubing work is shown in Figure 4 and consists of one hand-operated 2½-inch ID ram-type wireline preventer equipped with ¾-inch pipe rams surmounted by a 2½-inch wireline stripper. In service, an adapter flange is installed on the wellhead, and a space nipple of sufficient length is installed to mount the preventer equipment above the top circle of the well guard. In this manner, the well guard may be utilized to support the working platform and does not require removal prior to moving the work unit on location.

3. A pulling unit complete with high-pressure pump, manifold, measuring tanks, and all necessary tools to run and to pull ¾-inch, 1, or 1¼-inch tubing. Existing units (company and contract) are double pipe mast types. Their versatility, however, is limited to the handling of tubing in singles. Larger contract units capable of pulling doubles will soon become available and will not only facilitate the handling of small outside-diameter tubing but will also increase the life of the tubing. Because of the high friction loss in small outside-diameter tubing work, a triplex pump or its equivalent is mandatory.

The cementing, well-logging, and perforating techniques developed by service companies for permanent-type well-completion workovers are utilized to the maximum for concentric tubing work. Permanent-type completion cementing units are used on all jobs if possible, inasmuch as the slurry characteristics and blend of admixes can be more closely regulated. Through-tubing perforating equipment includes 1¾-inch and 1⅜-inch swing-jet, link-jet, and capsule-jet perforator. Selection of the

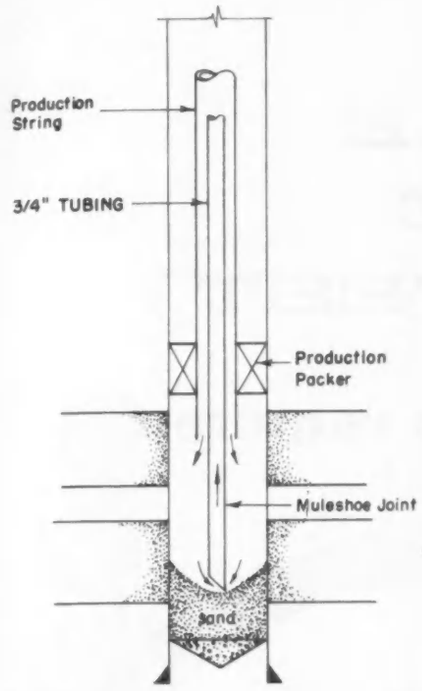


FIGURE 5—Sand removal utilizing concentric tubing technique with mule shoe joint.

size and type gun is dependent upon the size casing, size and condition of tubing and the perforating medium. Through-tubing combination gamma ray log and collar locator have also been advantageously used in concentric-tubing work.

Work over Procedures. Prior to initiation of concentric-tubing work, an analysis of well conditions is made and the proposed operations evaluated as in any other permanent-type completion workover. Here, problems peculiar to this type work are encountered, and a solution must be foreseen before attempting through-tubing work. Well installations must meet specific requirements, and the problem must be of such nature as to fall within the limits of concentric-tubing workovers.

Utilization of wireline tools is made to the fullest extent prior to concentric tubing workovers. A wireline tubing gage affords a means of ascertaining tubing bore and conditions and determines the presence of sand bridges. Circulating sleeves or side-pocket mandrels are blanked off if required.

Actual workover operating procedures presented herein are sand removal, squeeze cementing, cement removal, sand control, and acidizing. Many variations in operating procedure were encountered in the various workovers. However, a general sequence of operations was apparent in each job.

Sand Removal. The removal of produced sand from the tubing and well bore was the first application of concentric-tubing techniques and has been the principal use for the tool. The majority of applications involve ¾-inch tubing concentric within 2-inch tubing and utilize salt water as the circulating fluid. The ¾-inch tubing is equipped with a mule-shoe joint on bottom. Because of the high-pressure—low-volume characteristic of the circulating system as imposed by the high friction loss of the small outside-diameter tubing, a high-pressure triplex pump is required. The average pumping requirement at an operating depth of 8000 feet is 2500 psi pump pressure with a circulating rate of 15 gallons per minute.

During sand-washing operations, the ¾-inch tubing is jetted into the sand bridge, and sand is carried in suspension into the ¾-inch—2-inch tubing annulus. After approximately 40 to 60 feet of sand are washed, the blowout preventer is closed, and the sand is reverse-circulated from the well as shown in Figure 5. In this manner, the hole is reversed clean on every second connection. Sand removal is continued until the hole is washed to the desired depth.

The high pump pressures imposed upon the formation during reverse circulation have at times resulted in loss of returns. The loss of salt water into the formation through the perforated interval in most instances carries the sand into the cavity behind the casing. If sand is still evident, circulation is maintained down the ¾-inch tubing to relieve the back pressure imposed on the formation and complete sand removal. The average sand-washing rate computed from 16 successful jobs was 68 feet per hour.

Operating techniques in sand washing with ¾-inch tubing are variable and dependent upon the well conditions. Hard sand bridges which have defied removal by bailing or permanent-type completion methods have been successfully removed by spudding or rotating through the hard crust and circulating out with ¾-inch tubing. The positive well control afforded by the blowout-preventer arrangement allows removal of sand entering the well bore as a result of natural flow. Thus, sand may be produced and exhausted from the interval without removal of the ¾-inch tubing from the well bore. Shale, as well as sand, has been effectively recovered from wells.

Using ¾-inch tubing for removal of sand in 2-inch tubing was initially considered susceptible to many difficulties. The sticking or plugging of the small outside-diameter pipe as well as failures caused by rupture or thread parting were anticipated. The past work, however, has shown remarkably few failures of this nature. Parted tubing was experienced in only four jobs; plugged ¾-inch tubing occurred in only four jobs; and in no instance has there been stuck tubing which required a conventional rig for recovery. Since the advent of sand removal utilizing ¾-inch tubing and during the succeeding 18-month period, 58 wells have been cleaned out. Of this total, 24 jobs resulted in restored production, 26 wells were successfully cleaned out but failed to restore production, and eight jobs were considered failures. The failures were attributed primarily to crooked or mashed tubing and to obstruction such as wireline tools in the tubing string.

Squeeze Cementing. The unusual success of ¾-inch tubing as a well-cleanout tool led to an investigation of broadening its application to other phases of well workovers.

This was effected in the successful completion of a plugback job in February, 1957. Squeeze cementing with ¾-inch tubing has been limited to date to plugbacks. A set-through cement job has not been attempted. Nevertheless, it is believed that reconditioning of a completed interval is not beyond the scope of this tool.

Techniques and services developed in wireline permanent-type completion work have been utilized in ¾-inch tubing workovers. A modified light-weight cement is used and mixed with a batch tank mixer to assure uniform slurry and weight. In lieu of a batch tank mixer, the slurry may be circulated through the pump and tank until a uniform mixture is attained. Small slurry volumes, not greater than 12 barrels are generally used and have been found adequate in most cases. Volume requirements above 12 barrels are completed by stage cementing.

To facilitate removal of sand in

FRACTURE
ACIDIZE
SWAB *and* TEST

as many intervals as required

Product No. 677-C

... *in one round trip*

with BAKER RETRIEVABLE BRIDGE PLUG *and...*

SETS AND PACKS OFF AGAINST PRESSURE DIFFERENTIALS FROM EITHER ABOVE OR BELOW

After the Retrievable Bridge Plug has been run to the desired depth and released, it will automatically set and pack off against pressure differentials established from either above or below the tool.

CAN BE RUN IN AND RETRIEVED EASILY... OR MOVED AND RESET AS MANY TIMES AS REQUIRED

The number of times that the Retrievable Bridge Plug can be released, moved and reset is limited only by the number of operations in the well that require its use.

NUMEROUS ECONOMICAL APPLICATIONS

Used WITH the Baker Full-Bore Retrievable Cementer for:

(a) *Straddle Operations*
The distance to be straddled is not limited by the made-up length of tool.

(b) *MULTIPLE Zone or Selective Testing, Fracturing, Acidizing*

Used BY ITSELF for:

(a) "Down-the-casing" Fracturing or Acidizing

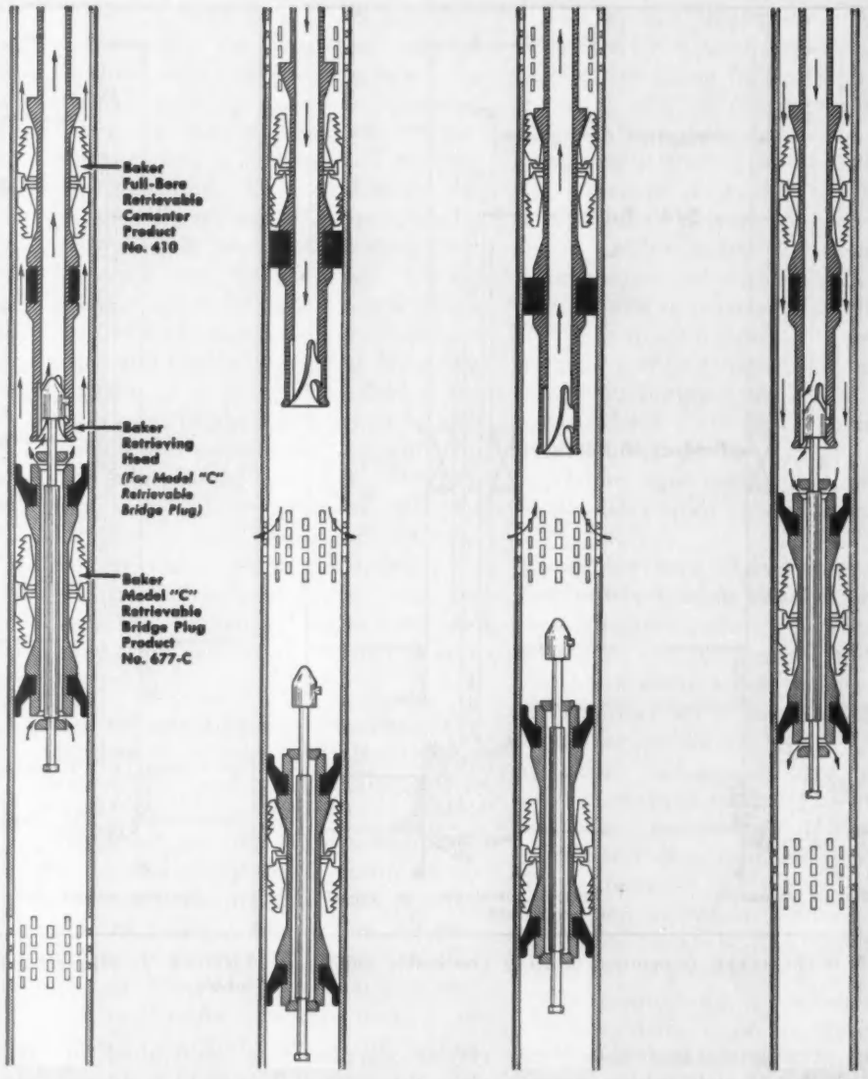
(b) Testing operations

(c) Temporary pressure containment to permit repair to or removal of well head equipment with safety.

Write for Catalog Supplement No. 319 for complete information on

TYPICAL OPERATION

Product No. 410


Baker Full-Bore Retrievable Cementer Product No. 410
Baker Retrieving Head (For Model "C" Retrievable Bridge Plug)
Baker Model "C" Retrievable Bridge Plug Product No. 677-C

RUNNING-IN
Retrievable Bridge Plug being run into well on bottom of Full-Bore Cementer through use of Retrieving Head. Note fluid by-pass.

FRACTURING OR ACIDIZING
Plug should be pressure tested after release. Cementer is released, raised above perforations and reset for pressure operations.

SWABBING, TESTING
Note how the reversal of pressure differential has transferred load from one set of slips to the other (both cementer and plug).

RETRIEVING
Plug and Cementer being moved to next set of perforations—or retrieved from well. Valves in plug open to permit fluid by-pass.

BAKER FULL-BORE RETRIEVABLE CEMENTER

HOLDS PRESSURE FROM EITHER ABOVE OR BELOW

Two sets of opposed slips enable the cementer to hold pressure from either above or below. Casing can be tested before squeeze—and the tubing also, if the Baker Full-Bore Tubing Tester is used.

FULL BORE CONSTRUCTION

Permits Passage of Tubing Perforators or Instruments—Assists in Preventing "Screen-Out" on Fracturing Jobs

The Full Bore through the Cementer (and Tester if used) is in reality a continuation of the bore through the tubing.

This continuous full ID passage not only permits passage of tubing perforators or instruments but assists in preventing "Screen-Out" (sand dropping out of the oil) and subsequent plugging of the tubing in fracturing jobs.

IDEAL STRADDLE TOOL WHEN USED WITH BAKER RETRIEVABLE BRIDGE PLUG

The operation of the Cementer setting mechanism makes it easy (through the use of the Retrievable Bridge Plug Retrieving Head) to release and pick-up the Baker Retrievable Bridge Plug. It is in fact the ideal partner to the Retrievable Bridge Plug for selective multiple-zone or single-zone operations.

these products and their application

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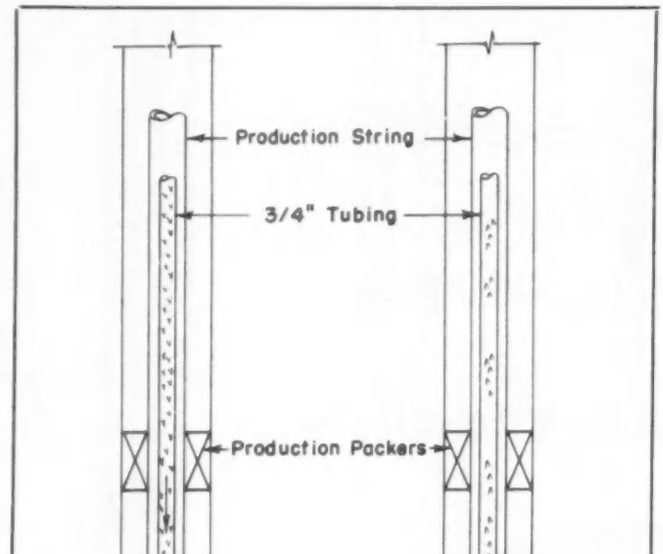

FIGURE 6—Squeeze cementing utilizing concentric tubing.

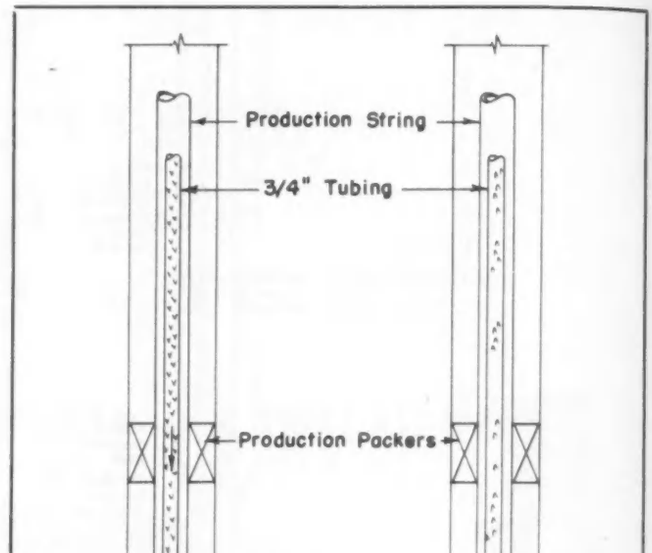

FIGURE 7—Displacement plug cementing utilizing concentric tubing.

plugback operations, a mule-shoe joint is run on the ¾-inch tubing string. The ¾-inch tubing is bottomed at the projected top of the cement plug, and the cement slurry is pumped down the ¾-inch tubing. Upon displacement of the ¾-inch tubing with cement, the blowout preventers are closed and the cement squeezed into the formation. Once the desired squeeze pressure is attained, the excess cement is reversed from the well and the ¾-inch tubing pulled approximately 30 feet above the new plug. An illustration of squeeze cementing is shown in Figure 6. Generally, 1000 psi pump pressure is maintained on the well after cutting the plug and clearing the tubing of excess cement. The plug is tagged, tested, and the ¾-inch tubing pulled after setting a minimum of 12 hours.

Plugback jobs in formations which cannot be pumped into are completed by the displacement plug method. The ¾-inch tubing is bottomed near the existing plug and the required volume of cement displaced into the well. After displacement, the ¾-inch tubing is pulled clear of the plug and reverse circulation is established to clear the tubing. The ¾-inch tubing is then lowered to the projected top of the plug, and reverse circulation is attained to assure clearance of the well bore to the proposed depth. This sequence is illustrated in Figure 7.

Squeeze pressures incurred in ¾-inch tubing plugbacks are not limited by the pressure rating of the casing as is the case in wireline squeeze cementing, inasmuch as all pressures are contained within and below the tubing string. Plugback operations have been successfully completed in wells equipped with retrievable production packers as well as retainer production packers. However, casing pressure is maintained as added assurance to prevent unseating of the packer or to avert crooked tubing. Maximum squeeze pressures have varied from 2000 to 2700 psi pump pressure.

Plugback jobs utilizing ¾-inch tubing have been successfully completed in nine wells; seven wells were restored to production. Two of the plugback jobs were single-string dual completions, two were completed in two-string dual completions and the remaining five were single well completions. Since the requisite of a circulating device to establish communication between tubing and casing is not essential to ¾-inch tubing workovers, a plugback job of single-string dual completions is completed without disturbing the upper completion.

Set-Cement Removal. The problem of set-cement removal has increased the complexity and, in some instances, has resulted in the failure of wireline workovers. Removal of a set-cement plug placed inadvertently too high in the well bore has been achieved by the use of acid through steel tubing with telescoping joints, and wireline tools with special bits have been used to remove cement filter-cake buildup in perforations. These methods have proved time-consuming and in some instances ineffective.

Set-cement removal using ¾-inch tubing techniques was recently completed in a well equipped with 5½-inch O.D. casing and 2-inch tubing. A diamond-point, shop-made bit was

run on ¾-inch tubing to the top of the cement plug, and inhibited super mud acid was pumped into the tubing. Utilizing air tongs, the ¾-inch tubing was rotated slowly with no perceptible weight applied on the bit. The acid was circulated down the ¾-inch tubing while rotating; upon displacement of the tubing volume, reverse circulation was established to wash the well bore. This procedure was repeated four to five times until the acid was spent. The spent acid was then discarded and a fresh volume spotted for further washing.

A total of 2500 gallons of acid was used in drilling 164 feet of set cement. Average penetration rate for the entire job (40 hours) was 4.1 feet per hour. However, actual penetration rate while drilling was computed to be 30 feet per hour. A calculated volume of 15¼ gallons of acid was required per foot of cement removed, or 500 gallons of acid would remove approximately 33 feet of cement. Removal of the cement was considered complete inasmuch as through-tubing perforating equipment recorded all casing collars, and no difficulty was experienced in reaching perforating depth.

Sand Control. The exclusion of formation sand is a problem characteristic of many wells in the Louisiana delta. In many instances the primary removal of sand has afforded restored production with little resanding of the well bore. For example, 35 percent of the wells cleaned out have continued to produce as sand-free wells. There are wells, however, in which extreme resanding tendencies are experienced. These wells require sand control to maintain continuous production. The mechanical means of sand control applicable to ¾-inch tubing workovers are sand-lock and sand-consolidating plastics.

Sand Lock. This process incorporates graded plastic-coated walnut shells pumped into and placed adjacent to the formation, using jelled oil as a carrying agent. The plastic coating bonds the hulls into a tight permeable network in the perforations and in the cavity between the sand face and the casing.

The sand lock process was completed in the lower zone of a single-string dually completed well. With the ¾-inch tubing bottomed at the base of the perforations, plastic-coated walnut hulls preceeded by diesel oil were displaced down the ¾-inch and spotted opposite the perforated interval. Walnut hulls concentrated in slurries of ⅛-pound per gallon to ¼-pound per gallon were squeezed into the formation until a "screen-out" pressure was reached. The well bore was cleaned by reverse circulation, and a second stage walnut-hull slurry was squeezed into the formation. During squeeze operations, the ¾-inch tubing was reciprocated as a precaution against plugging or sticking. However, rupture of a pump line during the final stage resulted in plugged ¾-inch tubing and necessitated a round trip to clean out the well bore. The well was then shut in a period sufficient to allow consolidation of the plastic-coated walnut shells. Completion in the treated interval failed; nonetheless, the mechanical aspects of the sand lock job were considered successful.

Sand-Consolidating Plastics. The advantages offered by ¾-inch tubing techniques and the recent developments in low-viscosity plastics prompted the use of the technique with sand-consolidating plastic in an attempt to control the sand production of a single completion. All pretreatment fluids and plastic were displaced down the ¾-inch tubing and spotted in the perforations prior to actual treatment of the formation, thus preventing contamination of the formation with workover fluid. During treatment, successive stages of plastic were squeezed with the required shut-in time allowed between stages. A total of 300 gallons was squeezed out in two stages; lease crude was utilized as an overflush between stages.

Although effective control of sand production was not realized, the mechanics involved in the application of sand-consolidating plastics were considered successful.

Acidizing. Mud acid treatments to dissolve clay and silt in sand formations and to remove mud blocks in screens have been used with varying degrees of success in well stimulation. These treatments did not disturb the production string but utilized the packer as a squeeze tool. Apparent disadvantages are that well fluids or workover fluids present in the tubing are squeezed ahead of the acid, and thus actual treatment may be confined to the more permeable sections of the formation.

The ¾-inch tubing technique has been effectively used for acidizing by placing the string below the producing sand to allow circulation of acid past the face of the formation. Sufficient acid is spotted to cover the entire screen or perforated section and is allowed to pervade the formation for 15 to 20 minutes. The spent acid is then displaced with a fresh batch and allowed to permeate for an additional 15 to 20 minutes. The remaining acid is then pumped into the formation to complete the job.

Four wells have been chemically treated utilizing this technique; these operations have resulted in increased productivity from two wells.

Economics and Advantages of Concentric-Tubing Workovers. An evaluation of the economics of permanent-type well-completion methods has shown many actual and potential savings which are realized in this technique for workovers. The hazards, limitations and past failures encountered in wireline workovers, however, led to an investigation for an improved and more economical method of performing the permanent-type completion operation. This was realized in the use of small outside-diameter tubing as a workover tool.

The methods of concentric-tubing workovers have been applied to a total of 71 jobs at the present time. Sand removal, by far the most common application, accounted for 58 jobs and resulted in the successful cleanout of 50 wells. Of this number, 24 were successfully restored to production and 20, or 35 percent, continued to produce as trouble-free wells. The average cost of a single well cleanout has been $1420. Based on an estimated conventional workover cost of $10,000 for single completions and $15,000 for duals, a net saving of $438,000 is estimated for the 50 successful cleanouts. Because of the small number of cleanouts accomplished with wireline tools in this area, a comparative cost is not available.

Plugbacks have been attempted in 11 wells with 9, or 82 percent, completed successfully. The average cost of a concentric-tubing plugback operation was $3611 compared to an average cost of $6000 for a wireline plugback. The minimum cost to complete a concentric-tubing plugback was $2359 with three days completion time. The estimated average conven-

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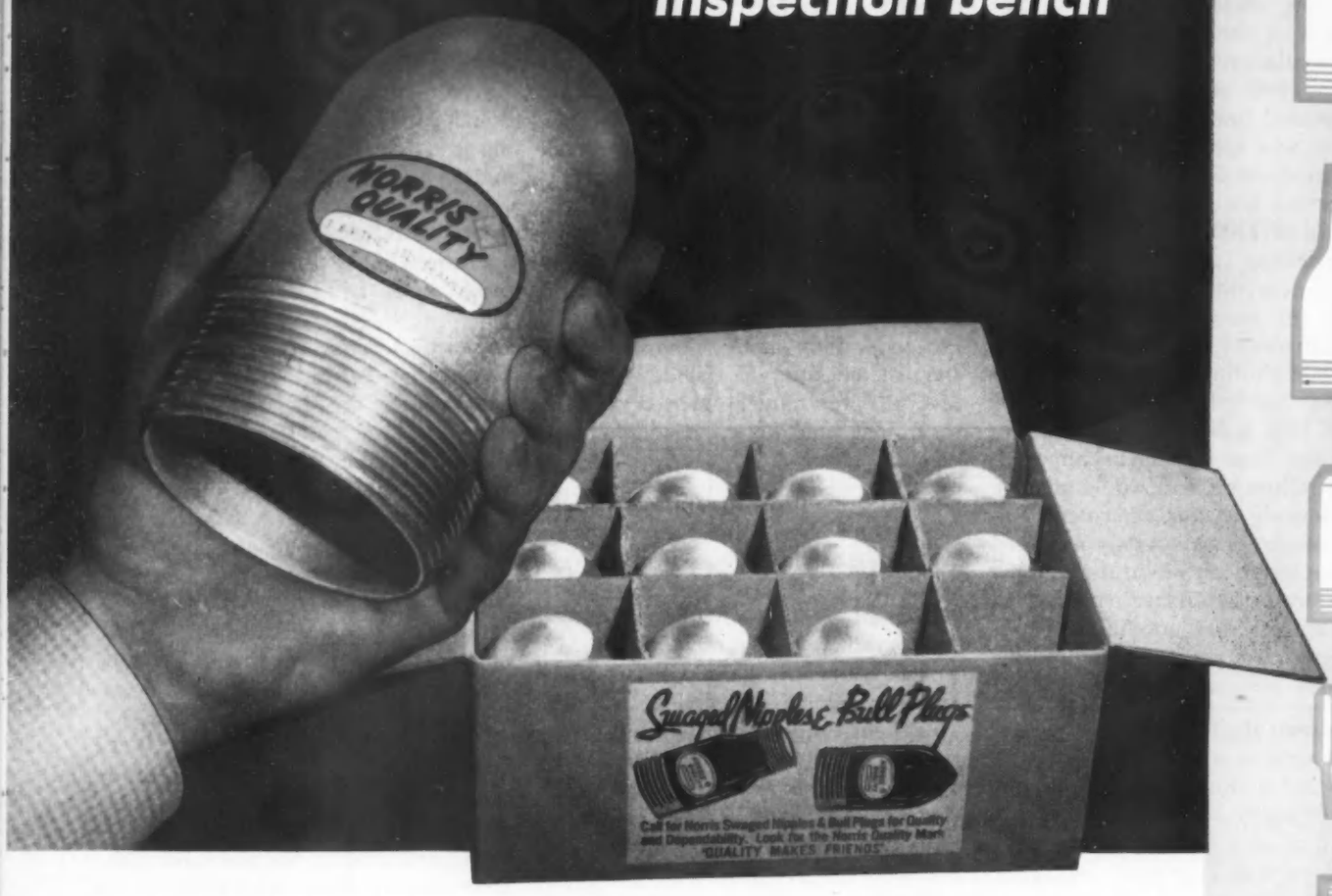

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TABLE 1—A Representative Group of Through-Tubing Workovers to December 1, 1957

Buras Area, Louisiana Delta—Sand Removal

Well No.	WELL DATA				Job Category	Actual Cost	Est. Cost w/Rig	Est. Net Savings	Results	Remarks
	Tbg.	Csg.	Perfs.	Type Compl.						
1	2″	5½″	8752–8755′	Dual-Single String	Sand Removal	$1,526	$15,000	$13,474	Washed tubing clear of sand, swabbed well, flowed short time and sanded up.	First attempt in the use of ¾″ tubing as a workover tool, 6-21-56.
2	2″	5½″	9166–9172′	Single Completion	Sand Removal	$2,761	$10,000	$7,239	Washed tubing and well bore without difficulty, restored production.	
3	2″	5½″	7938–7948′	Dual-Single String	Sand Removal	$2,383	$15,000	$12,617	Wash sand and mud from tubing and well bore, acidized and restored production.	Well continued to produce without difficulty.
4	2″	5½″	6730–6750′	Single Completion	Sand Removal	$1,853	$10,000	$8,147	Removal of sand, mud, and shale completed without difficulty. Failed to restore production.	Evidence of casing failure in the perforated interval noted during subsequent conventional workover.
5	2″	5½″	8004–8012′	Single Completion	Sand Removal	$529	$10,000	$9,471	Well cleaned out with no difficulty. Restored production at normal rate.	
6	2″	5½″	7275–7285′	Single Completion	Sand Removal	$1,500	$10,000	$8,500	Washed sand from tubing and well bore. Well resanded immediately.	Subsequent cleanout with ¾″ tubing revealed evidence of primary cement failure.
7	2″	5½″	9512–9518′	Dual-Single String	Sand Removal	$1,313	$15,000	$13,687	Completed sand removal without difficulty, restored production.	
8	2″	4″ Liner	8594–8608′	Dual-Single String	Sand Removal	$972	.....	.....	Washed sand to 8568′. Unable to wash below this depth. Failed to clean out.	Junk in 4″ liner at 8568′. Required conventional rig to complete cleanout.
9	2″	5½″	7270–7280′	Single Completion	Sand Removal	$1,332	$10,000	$8,668	Washed out series of sand bridges in tubing, swabbed in.	¾″ tubing parted in threads. Recovered fish with spear and swab line.
10	2″	5½″	9356–9366′	Dual-Single String	Sand Removal	$772	$15,000	$14,228	Washed out sand with no difficulty, restored production.	
11	2″	5½″	8646–8670′	Single Completion	Sand Removal	$1,025	$10,000	$8,975	Cleaned out tubing and well bore without difficulty. Well sanded immediately after cleanout.	Subsequent well cleanout with ¾″ tubing resulted in resanding.
12	2″	5½″	8206–8230′	Single Completion	Sand Removal	$870	$10,000	$9,130	Washed sand from the tubing and well bore. Well resanded after cleanout.	Reconditioning attempt at later date revealed bad casing in the perforated section.
13	2″	5½″	7468–7475′	Single Completion	Sand Removal	$1,768	$10,000	$8,232	Washed out sand to top of fish (169′ of 1″ Al. pipe). Ran fishing tool on swab line, recovered fish and completed sand removal, restored production.	Aluminum pipe lost in hole during previous work utilizing wire line methods.
14	2″	5½″	5648–5653′	Single Completion	Plugback	$3,706	$15,000	$11,294	Washed sand from tubing and well bore, squeezed perfs. 5822-42′, recomp. 5648-53′. Cleaned out well bore, swabbed 100% S.W., well P/A.	Initial plugback job conducted in the Buras Area utilizing ¾″ tbg. technique.
15	2″	5½″	7463–7480′	Dual-Single String	Plugback	$2,650	$20,000	$17,350	Washed sand from tubing and well bore, squeeze cemented perfs. 7652-7664′; cut plug at 7585′. Well recompleted thru perfs. 7463-80′.	Casing well producing during workover.
16	2″	5½″	6840–6853′	Single Completion	Plugback	$1,210	.....	.....	Mechanical aspects of plugback completed without difficulty. Breakdown of old perforations above proposed interval prevented successful re-completion.	
17	2″	5½″	8561–8565′	Dual Single String	Plugback	$3,200	$20,000	$16,800	Squeeze, cemented perfs. 8594-8600′ in two stages. Tagged plug high. Drilled cement from 8562′ to 8576′ with ¾″ tbg. Perforated 8561-8565′. Completed as top allowable oil well.	Washed and drilled cement plug without difficulty.
18	2″	5½″	6496–6505′	Single Completed	Plugback	$3,149	$15,000	$11,851	Mixed and squeezed total of 50 sx modined cement in two stages with max. squeeze pressure of 1500 psi.	Well recompleted as gas well.
19	2″	9⅝″	8156–8172′	Dual-Two String	Plugback	Work Unit $6,685 W/O Rig $42,840	$20,000	.....	Failed to reach total depth with ¾″ tbg. Required use of conventional w/o rig to change out crooked tbg. ¾″ tbg. utilized to spot cement plug from 8696-8532. Well successfully recompleted.	Excessive costs due to extensive fishing during w/o to change out tubing.
20	2″	5½″	7141–7144′	Single Completion	Plugback	$2,365	$15,000	$12,635	Failed to break down formation with 2000 psi. Spotted cement plug from 7197′ to 7165′.	Well recompleted as gas well.
21	2″	5½″	8802–8810′	Single Completion	Plugback	$2,798	$15,000	$12,202	Squeezed 4½ bbls. cement in perfs. 8848-8855′ w/ max. 2700 psi. Cut cement plg at 8820′, perf. 8802-8810′. Well successfully re-completed.	Job completed in 42 hours.
22	2″	7″	7376–7388′	Dual-Two String	Plugback	$2,359	$20,000	$17,641	Mixed and squeezed 30 sx modined cement in perforation 7442′-7445′ with max. 1800 psi. Cut cement plug at 7420′.	Recompleted as top allowable oil well without difficulty.
23	2″	5½″	7238–7252′	Dual-Single String	Sand Removal & Sand Control	$6,160	$15,000	$8,840	Washed out tbg. and well bore; sandlocked perforations. Failed to complete. Extended perfs. in subsequent workover.	First use of ¾″ tubing in operations other than sand removal.

Continued on Next Page

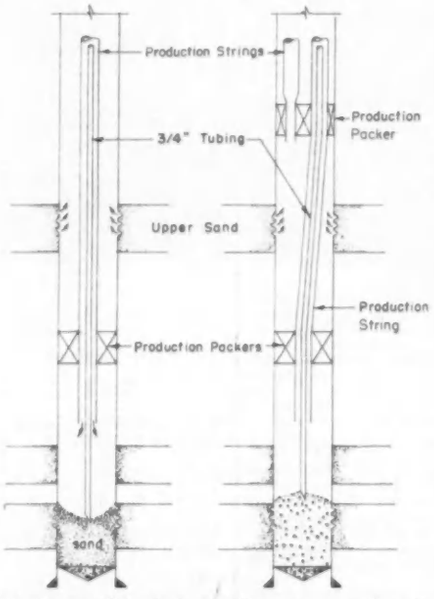
TABLE 1—A Representative Group of Through-Tubing Workovers to December 1, 1957—(Continued)

Buras Area, Louisiana Delta—Sand Removal

Well No.	WELL DATA				Job Category	Actual Cost	Est. Cost w/Rig	Est. Net Savings	Results	Remarks
	Tbg.	Csg.	Perfs.	Type Compl.						
24	2″	4″ Liner	6720–6726′	Single Completion	Sand Control	$4,463	$10,000	$5,537	Washed sand from 2452′ to 6728′. Pumped 200 gal. sand consolidated plastic in formation.	Plastic failed to curtail sand production. Well resanded while swabbing.
25	2″	5½″	7432–7438′	Single Completion	Sand Removal & Acidize	$2,145	$10,000	$7,855	Washed to 7,390′ and acidized, failed to produce.	
26	2″	5½″	7696–7707′	Single Completion	Sand Removal & Acidize	$1,648	$10,000	$8,352	Bottomed ¾″ at 7709′ and spotted acid in screen liner, pumped in remainder of acid, restored to natural flow.	
27	2″	5½″	7170–7174′	Single Completion	Plugback & Set Cement Removal	$7,208	.....	.....	Washed out sand from tbg. and well bore, squeeze cemented perfs. 7264-70′. Tagged cement plug 170′ high drilled out set cement 7030-7200′, utilizing super mud acid. Perforated 7170-74′. Sanded up on gas lift.	This workover exemplified the use of ¾″ tbg. in set cement removal. Cement was drilled at the rate of 4′ per hour with 15 gals. acid required per ft. of cement in 5½″ casing.

THROUGH-TUBING WORKOVER SUMMARY

		No. of Jobs
Sand Removal	—Successful well cleanout and improved production	24
	Successful cleanout only	26
	Failed to cleanout	8
Recompletions	—Successful plugback and improved production	7
	Successful plugback only	2
	Workover failed	2
Sand Control	—Sandlock perforations	1
	Sand consolidating plastic	1
	Total Number of Jobs	71
	Total Net Savings	$552,155.



Sand removal in single string dual completion. **Squeeze cementing in parallel string dual completion.**

FIGURE 8—Adaption of through tubing workover techniques in dual completed wells.

tional workover cost is $15,000 and $20,000 for single and dual completions. Thus, an estimated net saving of $99,773 was experienced in plugbacks alone.

The latent monetary saving of concentric-tubing workovers is exemplified in the ease with which dually completed wells have been worked over. Workover of the lower zone has been completed in 20 single-string, dually completed wells. At no time was the upper zone closed in or otherwise disturbed during actual operations. This is shown in Figure 8. Reservoir damage to the upper zone frequently encountered during conventional dual workovers, as well as the production loss during the workover period, was excluded or reduced to a minimum with the ¾-inch tubing techniques.

A representative group of workovers attempted as of December 1, 1957, noting comparative costs of concentric-tubing and conventional rig workover, is presented in Table 1. The cost estimate of conventional dual-completion workovers was increased $5000 above the cost of single well workovers. However, past experience has shown extensive fishing costs and lengthy workovers to be prevalent during conventional dual workover operations.

A comparison of wireline and concentric-tubing workover operations reveals the following advantages in this new concept:

1. Equipment requirements are no greater than that of a conventional completion and the high initial cost of the permanent-type completion installation is thereby curtailed.

2. The hazards of wireline work are eliminated.

3. Squeeze pressures during cementing are not confined to the pressure rating of the casing inasmuch as all pressure is contained within the tubing and below the production packer.

4. Sand removal is completed at a much faster rate and offers greater flexibility.

5. Workover of the lower zone in a single-string dually completed well is carried out without disturbing the upper zone.

6. Limitation of sand coverage is not dependent upon the amount of 1-inch aluminum pipe that can be safely handled.

7. Workover costs are lower than those of wireline methods.

Conclusions. It is evident that a tool has been developed which may be the greatest single advancement of well-workover technique since the initiation of permanent-type well completion.

The simple work procedure, low cost, and outstanding success of concentric-tubing workovers will amplify and improve the principles of permanent-type well completions.

ACKNOWLEDGMENT

This article was originally presented as a paper at the spring meting, Division of Production, American Petroleum Institute, February, 1958, Houston, under the title of "Report on the Methods and Results of Concentric-Tubing Workovers." The author wishes to express his appreciation to the Gulf Oil Corporation for permission to publish this article.

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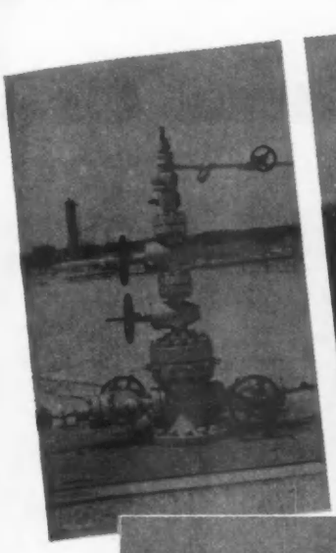

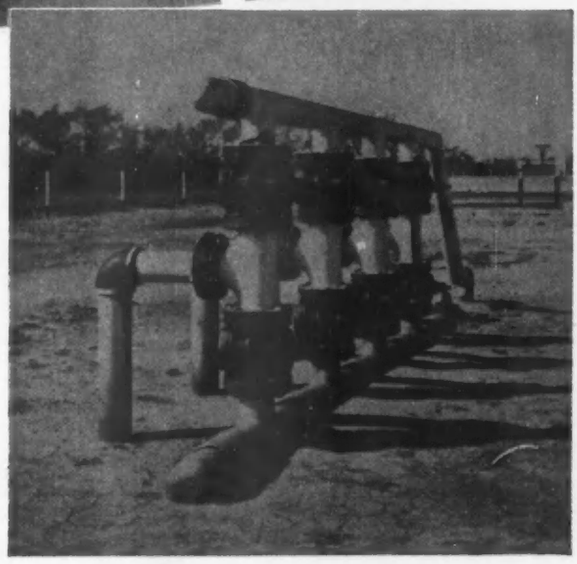

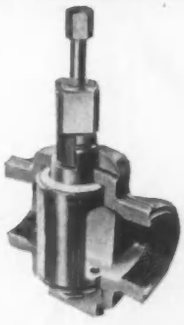

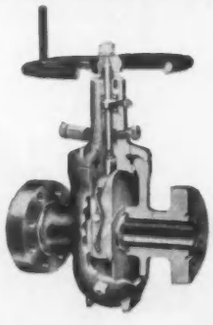

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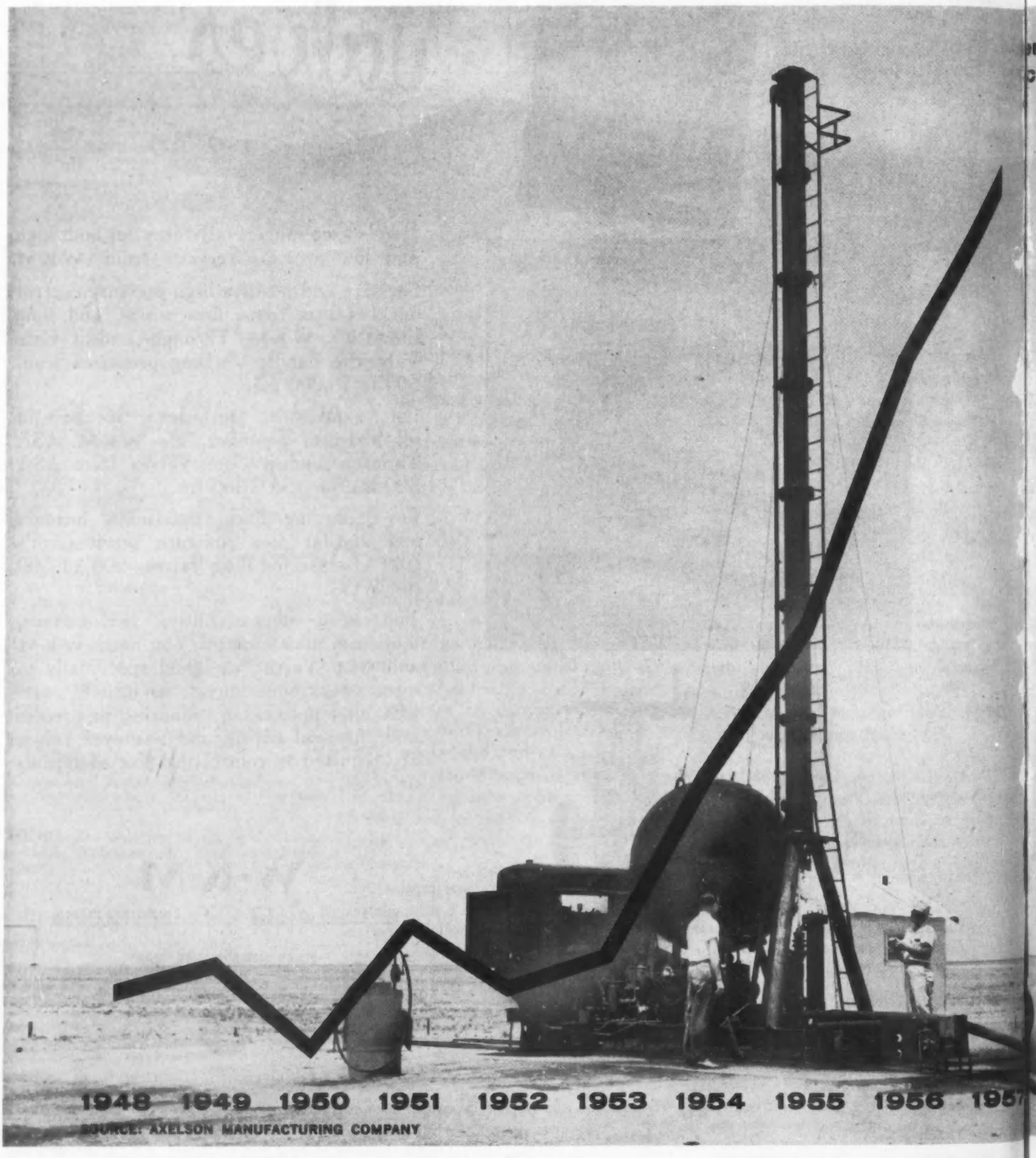

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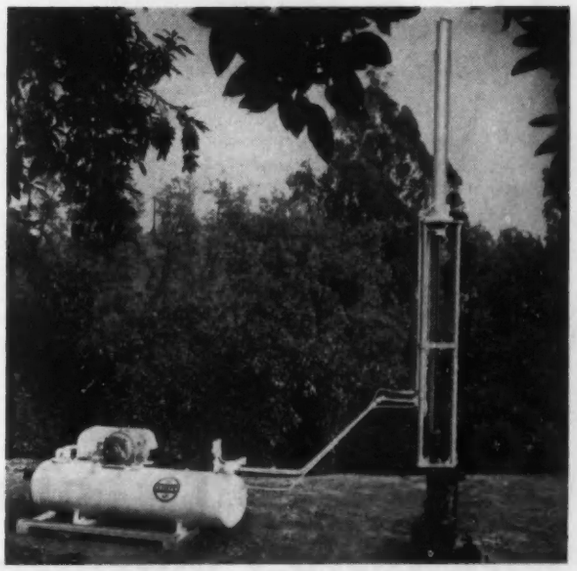

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FIGURE 1—Dark area indicates concentration of active interest in Spraberry-Clearfork.

Combination Treatment Spurs Spraberry-Clearfork Output

A high volume treatment of hydrochloric acid, sand and oil mixed at the surface and injected as a single treatment has made possible the economical completion of wells heretofore thought to be unproductive.

By T. D. Pugh,
Halliburton Oil Well Cementing Company, Midland

INTEREST IN the Spraberry Trend area of West Texas was revived in early 1955 by the discovery of Clearfork production. Wells producing from the Spraberry formation were declining and the gas-oil ratio was increasing. By mid-summer of 1956 some 300 Spraberry wells had been plugged back and re-completed in the shallower Clearfork pay. While this was quite a windfall to well owners, it did not appear to be profitable to drill a new well for Clearfork production.

Some extension wells were drilled in the hope of finding economical production, and a remarkably simple procedure was developed for a combination acid and fracturing job. As a result, many wells which had been considered marginal became profitable producers. An application for a patent on this combination acid, oil and sand treatment has been made by J. E. Jones, a drilling contractor.

This type of treatment presents the industry with a new technique for handling a difficult situation. The application is not complex and the results are excellent. It has been largely responsible for the drilling and completion of a large number of wells to the Spraberry-Clearfork formation. With proper application, it should help other formations with similar characteristics.

The Clearfork, a Permian development, is 900 to 1000 feet above the Spraberry at 6000 to 7000 feet subsurface and is similar to the Spraberry. It is inherently fractured and has low porosity. The permeability may average less than one millidarcy. The oil, a sweet crude of 35-45 degree API gravity, is thought to be held within the fractures, and is thought to produce by gas-solution drive.

Geological and reservoir data on the Clearfork in this area were very limited. When the Spraberry was being developed, the Clearfork was discounted as being non-productive. Few cores were available and most electrical logs logged the Spraberry only. The meager information available coupled with radio-active logs served for re-completion activities. There are indications of as many as five productive stringers separated by substantial shale sections. Figure 3 is a typical radio-active log of the Spraberry-Clearfork.

This section is quite different from the Clearfork which is generally found in the Permian Basin. For example, the Clearfork of the Goldsmith area is a thick dolomite that is relatively clean with less prominent

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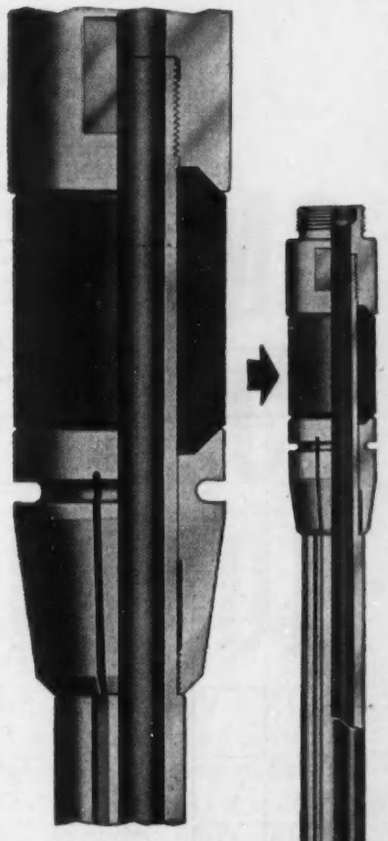

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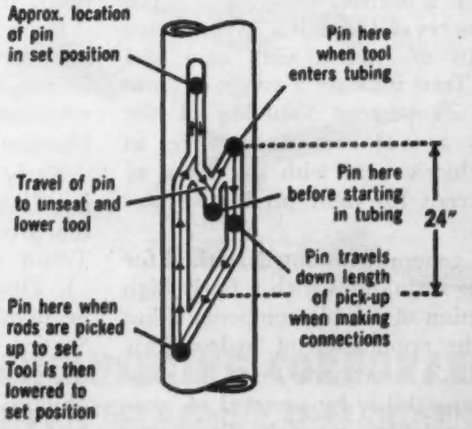
Approx. location of pin in set position
Pin here when tool enters tubing
Travel of pin to unseat and lower tool
Pin here before starting in tubing
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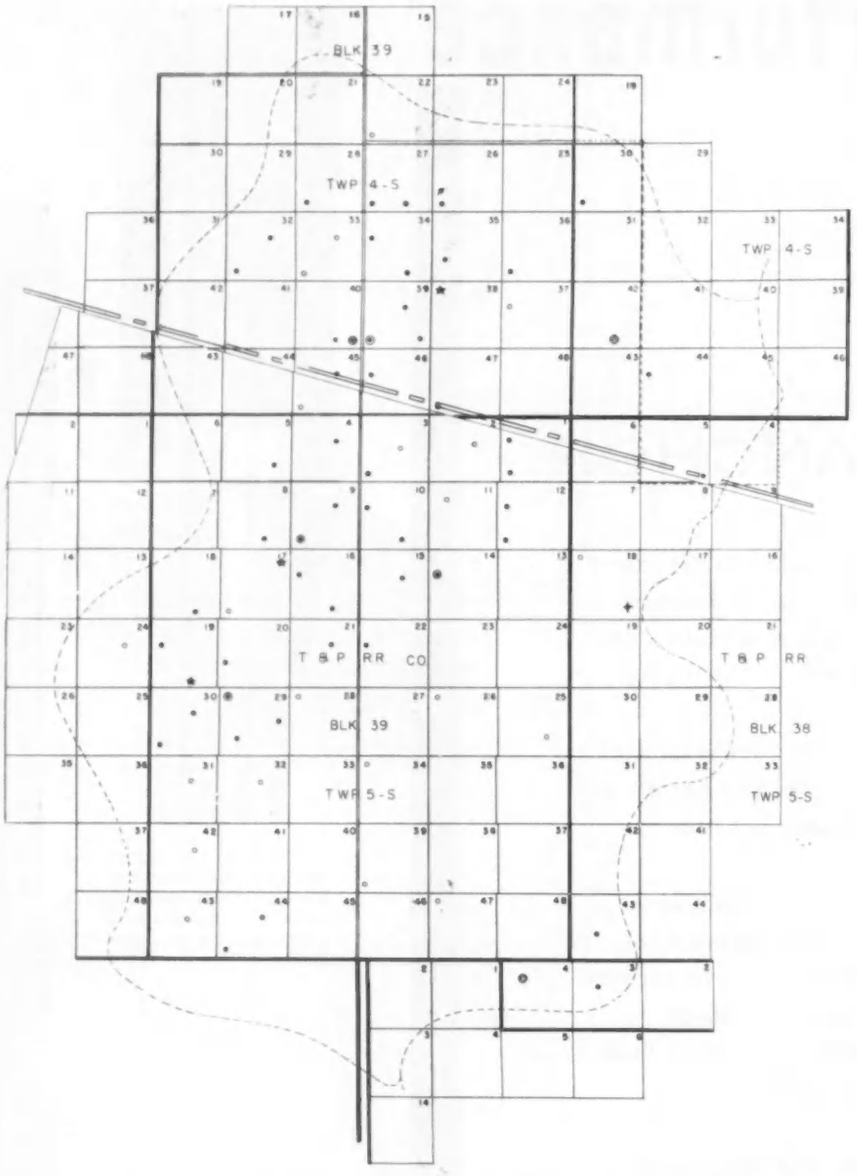

FIGURE 2—Close-up of dark area in Figure 1 showing locations of Clearfork interest.

shale stringers and produces a sour crude typical of West Texas Permian formations. Unlike the Spraberry, calcite is a primary component of the Spraberry-Clearfork with lesser amounts of quartz, silty clay and shale. Tests indicate a range of from 20 to 90 percent solubility of the calcite, as calcium carbonate, in hydrochloric acid with minimum of 75 percent for most productive sections.

The generally accepted method for treating formations with a fairly high proportion of soluble components has been the application of hydrochloric acid. This treatment helps increase the permeability by removal of some of the soluble materials. For many formations it is necessary to include additives to aid in preventing emulsification of the oil and acid and/or the products of reaction which might result in permeability impairment.

Recently, fracturing treatments have been used for systems with inherent fractures. These treatments consisted of thickened acids and combination acid-fracture treatments.

Early in 1956 the J. E. Jones Drilling Company began drilling west of the proven section of the Spraberry Trend area (darkened area Figure 1). Deep tests had been drilled in Sections 40 and 30 of TWP 4, and Section 17 and 19 of TWP 5, Blk. 39, T&P Railroad Company's survey (Figure 2). Three other deep tests had been drilled on the extremes of the present area. All of these tests had been abandoned as dry. Maps of the area prior to 1956 do not log a top for a Clearfork section.

By July 1956, information indicated a Clearfork section similar to the productive sections to the East. Figure 3 shows the comparison of these two sections. There were indications of sufficient producible oil. It was also evident that the results of established completion techniques would not justify extensive drilling. Normal completion practice included use of a mud cleanout agent composed of hydrochloric acid and a special surfactant. The well was swabbed to remove mud contamination and establish production, after which it was treated with 2000-3000 gallons of non-emulsifying acid.

Various combinations of fracturing were tried with special emphasis on thickened acid and those combinations especially recommended for acid soluble formation. The results of these fracture treatments were no better than treating with acid alone.

Jones decided that to properly place the treatment, acid and fracturing fluid should be pumped *simultaneously* into the well, and a proper placement technique was devised.

In July the first combination acid, oil and sand treatment was performed. The treatment consisted of 20,000 gallons refined fracturing oil, 30,000 pounds sand, 2000 gallons hydrochloric acid and a suitable quantity of non-emulsifying chemical with an injection rate of 21.0 bpm. As a result of the treatment production in-

About The Author

T. D. Pugh, Jr., received his B.S. degree in chemical engineering from the University of Arkansas in 1947 after serving in the Navy. He joined Halliburton Oil Well Cementing Company's field operations in Kansas and is currently assistant division engineer in their Midland, Texas, division.

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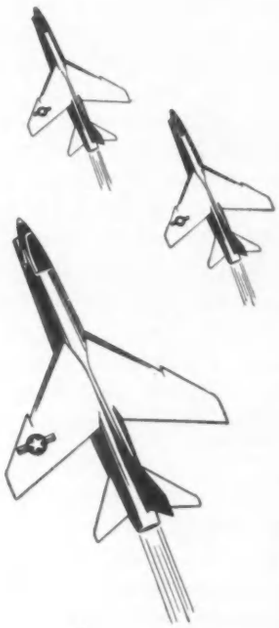

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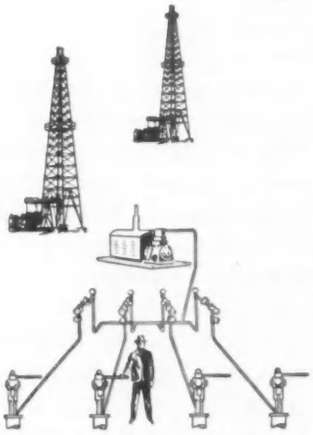

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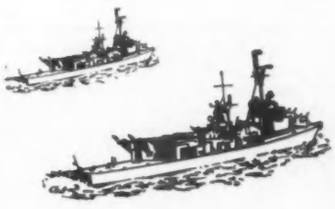

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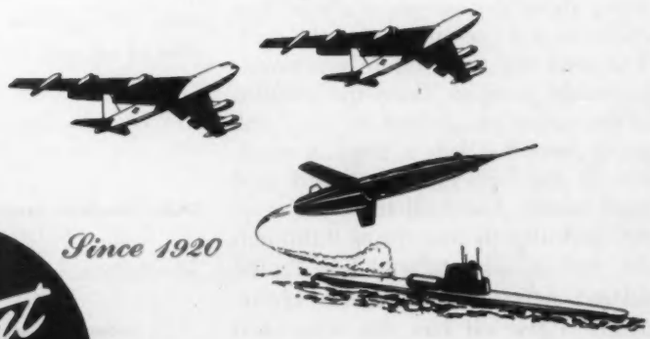

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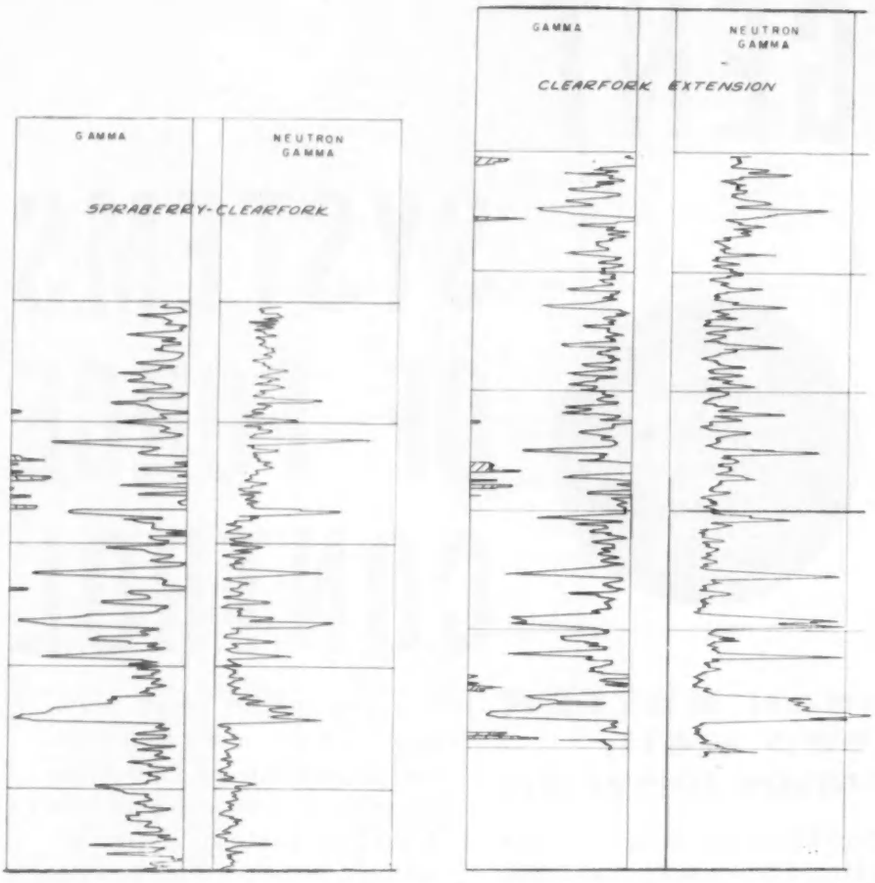


FIGURE 3—Gamma ray neutron logs comparison of typical Clearfork sections Spraberry trend, Pembrook and Blk 39 areas.

creased from 85 bopd swabbing to 205 bopd flowing.

Six treatments were performed the first month. Five of the wells subsequently flowed well above allowable capacity. One well increased several fold but was temporarily abandoned. Details of these jobs can be found in Table 1.

Originally the acid was pumped down tubing which was run to a few joints above the top perforations. The chemical was pre-mixed with the acid. The sand and oil mixture was simultaneously pumped down the annulus of the casing and tubing, as there was some concern about a possible emulsion if the heavy frac oil and acid were mixed. Later all materials were pumped directly into the well through the casing. The tubing is not considered necessary in present treatments. Lease oil has also been used successfully on several jobs.

In general it is recommended that the treatments be consistent with general fracturing practices for similar type formations of the area. High injection rate is the usual practice in West Texas with the sand and oil being properly proportioned. Temporary plugging materials and fluid loss additives may be used if desired and the treatment followed with the desired amount of flush.

Some experimentation was necessary to determine the proper acid-oil ratio. At the present time the most effective ratio is 1:3. The average job uses 7000 gallons of acid, 21,000 gallons of oil and 31,500 pounds of sand.

The effect of these developments has been quite evident. In October 1955 the area outlined in Figure 2 showed no active locations, no producing wells and 7 dry holes. In June of 1957, the same area had 23 active locations, 53 producing wells and 5 dry holes. Three deep tests originally abandoned as dry have been completed as Clearfork wells. These wells are marked with an asterisk in Figure 2. It has been necessary to treat most of these wells with the new combination treatment in order to obtain sufficient oil to make further drilling economical. The change of lease agreements in this area is further indication of the added interest.

The present production outlines an area of approximately 100,000 acres. This is about equal to half of the proven Clearfork area of the Spraberry Trend. It is believed that the area will be extended in the near future.

The reason for running the frac and acid materials simultaneously was the apparent inability of acid and fracturing to "treat" the same section in sequence operation. This and other field observations have indicated that the injection profile of a formation may be quite different for different injection rates. There has been evidence that a different injection profile can be obtained by changing the injection rate from a few gallons per minute to several barrels per minute. No equipment is presently available which can measure a profile under the conditions of a fracture. However, it is conceivable that only under the same pumping conditions will the same zone be treated in the same manner.

ACKNOWLEDGMENT

The author wishes to thank Midland Map Company for permission to reproduce the maps used in Figures 1 and 2, Welex Incorporated for permission to reproduce the logs used in Figure 3 and also the management of Halliburton Oil Well Cementing Company for permission to publish this article.

TABLE 1—Well Stimulation Treatment and Production Data of First Six Wells That Used the Combination Treatment

Well	Gallons of Oil	Pounds of Sand	Gallons of Regular Acid	Gallons of Chemicals	Barrels of Flush	PRESSURES PSI		Average Total Injection Rate BPM	PRODUCTION BOPD	
						Maximum	Minimum		Before	After
A	20,000	30,000	2000	200	360	3300	2500	21.0	85	205
B	16,000	24,000	4000	220	368	3400	2500	21.5	89	287
C	20,000	40,000	5000	250	350	3500	1000	19.3	90	331
D	20,000	30,000	5000	250	398	3400	2800	20.6	0	160
E	21,000	31,500	5000	250	360	3500	2800	18.7	72	341
F	21,000	31,500	5000	250	258	3000	2200	22.9	0	30–40

For Your PRODUCTION File

Part 4 in a series on reservoir engineering

Determining Water Influx From Production Data

By Frank W. Cole
Assistant Professor Petroleum Engineering
School of Petroleum Engineering
University of Oklahoma, Norman, Okla.

DETERMINING WATER influx into an oil reservoir may be a major problem for the engineer studying the behavior of a reservoir. A previous article developed a method for calculating the change in depth of an oil-water contact using production data and the Darcy flow equation. As pointed out in the article, this method has certain limitations but is very useful in many cases. If a cross section of the reservoir is available and the change in the oil-water contact is known, along with certain other reservoir data, the water influx into a reservoir can be determined. Expressed as an equation, the net water influx is:

$$(W - w) = \frac{\overbrace{\left[(h_w)\ (A_{ow})\ (\Phi) \right]}^{(A)} \overbrace{\left[(1 - C_w - S_{or}) \right]}^{(B)}}{5.615} \quad (1)$$

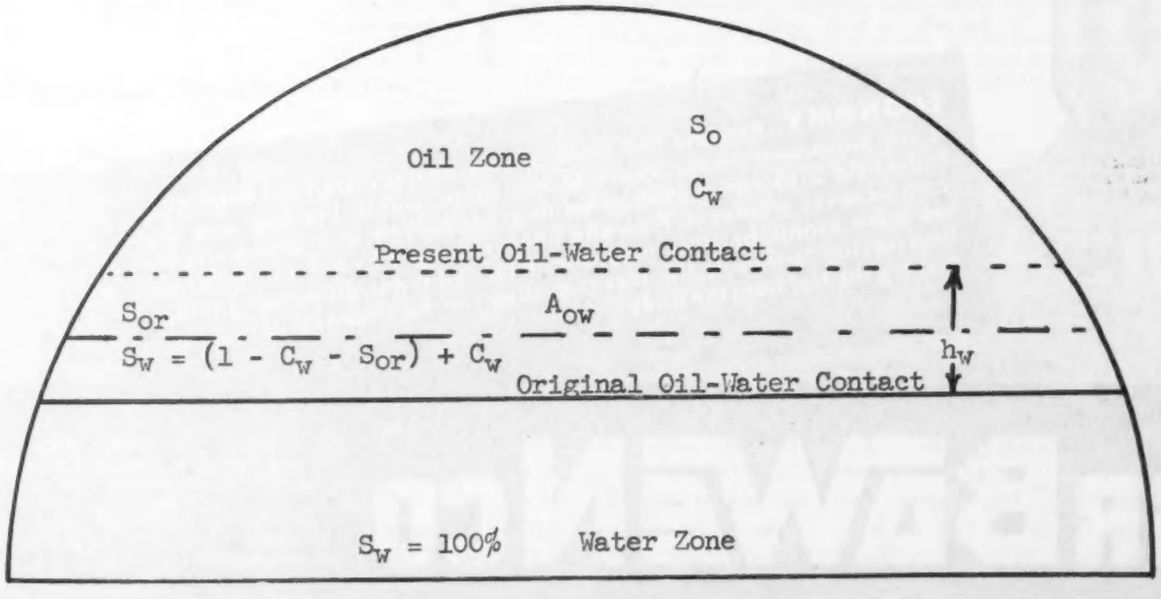
Analysis of Part A of Equation 1 shows it to be the volume of the reservoir into which the water has migrated. Part B is that portion of the pore volume of the invaded area which will be occupied by the invading water.

This method has the same limitations as the method used to calculate h_w, that is, (1) no oil-water transition zone, (2) no water coning. Other methods which can be used to calculate h_w for a solution of the net water influx, at the time the water influx data are needed, include electrical logging, radioactivity logging, drill stem testing, and coring. Figure 1 illustrates saturation distributions involved in a changing oil-water contact.

NOMENCLATURE

W = gross water influx into original oil zone, bbls
w = water production, bbls
h_w = change in depth of oil-water contact, ft
A_{ow} = average cross-sectional area flooded by water, sq ft
Φ = porosity, fraction
C_w = interstitial water saturation, fraction
S_{or} = residual oil saturation after flooding with water, fraction
S_o = original oil saturation in oil zone, fraction
S_w = water saturation, fraction

TO BE CONTINUED



Change in Oil Water Contact

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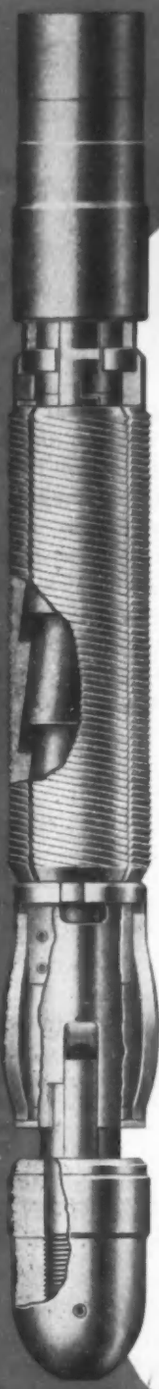

Full Circle Type Bowen Releasing Spear for casing

Safety Ring Pack-off

SECURE ENGAGEMENT—Full Circle Type Bowen Releasing Spears utilize novel Full Circle Slips that contact virtually the entire inner surface of a long section of the fish, and in addition, the entire inner circumference of the Full Circle Slips is backed by tapers on the spear body. Consequently, when a fish is engaged and upward pull is exerted, the expansion strain is spread so evenly over so much of the inner surface of the fish that there is no fish distortion. Comparisons show that this Spear has from 35% to 450% more useful slip engagement area than any other spear on the market today! Full Circle Spears insure the operator that there will be no loss of engagement regardless of the degree of the upward pull and regardless of the intensity of the jarring blows. On numerous actual jobs, in conjunction with hydraulic pulling tools and jars, pipe has been pulled and jarred in two below the Full Circle Type Bowen Releasing Spear with no distortion at the point of engagement.

VERSATILITY—All Full Circle Type Bowen Releasing Spears can be equipped to pack off the fish simply by removing the Safety Ring and by installing in its place a Safety Ring Pack-off. This one-piece pack-off attachment utilizes the circulation pressure to seal its rubber into a leak-proof fit against the inner walls of the fish. The radically different design of Full Circle Type Bowen Releasing Spears permits the use of other accessories which insure:

Alignment of the Spear with the fish.

Penetration of the fish to any desired depth.

Entrance of the Spear into a battered or sand-plugged fish.

Full Circle Type Bowen Releasing Spears are available for use with both right hand and left hand fishing strings.

Full Circle Type Bowen Releasing Spears are ideal to use with a Bowen Internal Cutter to perform cut and pull operations.

POSITIVE RELEASE—As their primary releasing mechanism, Full Circle Type Bowen Releasing Spears provide means for hanging and supporting the Full Circle Slips in their uppermost position relative to the spear body. When in this position, the Full Circle Slips cannot be expanded against the fish by the tapers on the spear body and the spear can be easily withdrawn from the fish. As a secondary releasing mechanism, left-hand wickers are cut on the Full Circle Slips to permit unscrewing from the fish. Full Circle Spears can be engaged with and released from a fish indefinitely without being withdrawn from the hole. The releasing mechanism is unaffected by excessive pulling strains, terrific jarring blows, and adverse well conditions.

SAFETY—All Full Circle Type Bowen Releasing Spears are engineered to provide greater tensile strengths than the tensile strengths of the pipe sizes that they engage. The Full Circle Slips are designed to collapse below the outside diameter of the Safety Ring or the Safety Ring Pack-off. This feature insures the Spear's ability to release from any fish that it has penetrated. The Full Circle Slips encompass so much of the inner area of the fish that it is virtually impossible for any junk to fall alongside and foul the mechanism of the Spear. Although each Full Circle Slip individually engages with and releases from the fish, a Unitizer is provided to make the slips work together in the event that a misshapen fish is encountered.

Available in tubing and drill pipe sizes.

ECONOMY—Because Full Circle Spears do not distort the fish, there is no movement under strain of the spear within the fish and the Full Circle Slips can be subjected to great pulling and jarring strains with no wear whatever. Pipe and liners salvaged by Full Circle Spears are more usable because they are neither split nor distorted. Another time-saving feature is the fact that slips can be changed without removing the Nut from the Body.

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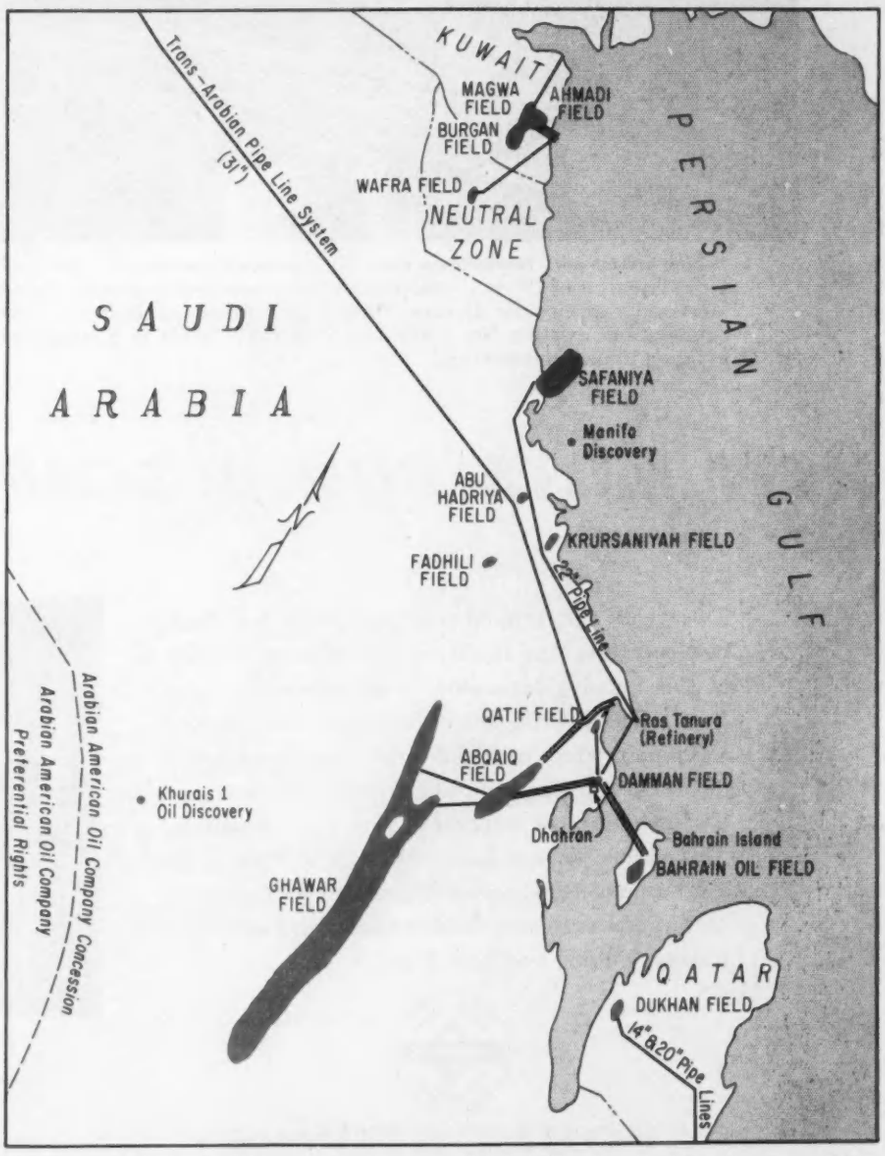
Manifa Is Second Persian Gulf Offshore Discovery

Aramco's new field is eight miles from land and 20 miles southeast of Safaniya, first offshore field.



Arabian American Oil Company has opened a second offshore oil field in the Persian Gulf, off the Saudi Arabian coast. It is the Manifa field, near the center of this map. This area is eight miles from land. It is about 20 miles southeast of Safaniya, the first offshore field in the Persian Gulf.

By H. T. Brundage, WORLD OIL Staff

ARABIAN AMERICAN Oil Company wound up a spectacular exploration year in 1957 with the discovery of oil at Manifa in the Persian Gulf. The offshore wildcat is located 120 miles northwest of Dhahran and eight miles offshore. It is about 20 miles southeast of Safaniya field, the first offshore field in the Persian Gulf, found by Aramco in 1951.

The find at Manifa appeared to be a major field. The offshore drilling barge "Queen Mary," used previously for development drilling at Safaniya after being purchased by Aramco from Creole Petroleum Corporation in Venezuela, was employed to drill the Manifa test. Since Safaniya has been on production since April, 1957, it appeared that the "Queen Mary" would be used to drill at least four more wells at Manifa to outline the new field.

The Manifa test was spudded on September 30, 1957. Both upper and lower Bahrain sands and the Zubair zone of the Cretaceous section were found to be unproductive. This was disappointing, as both Bahrain and Zubair horizons are productive at nearby Safaniya field. Crude oil from the Bahrain sands is now much in demand because of its high fuel oil yield, and it is also sweet.

The shallowest horizon capable of oil production is the Sulaiy limestone, just above the anhydrite cap rock of the Arab Zone (Jurassic). It was expected that future tests would have to be made to determine the productive capacity of the Sulaiy. Seven-inch casing was set at 8730 feet, above the Arab "A" member (Jurassic). Discovery of the main pay was in the Arab "A" member, where a drill stem test between 8747 and 8794 feet brought gas to the surface in 3 minutes and oil in 20 minutes. The crude is 28 gravity API and is sour.

The top of the Arab "C" member was reported at 8963 feet. A drill

Tubing stretch mill, Youngstown, Ohio. Electronically controlled mill to be completed during second quarter of 1958 . . . will provide increased production for Tubing comparable to our increased capacity for Casing. Both Upset Finishing Mill and this facility will greatly augment our existing No. 1 and No. 2 Seamless Mills in Youngstown. Photo shows mill building under construction.

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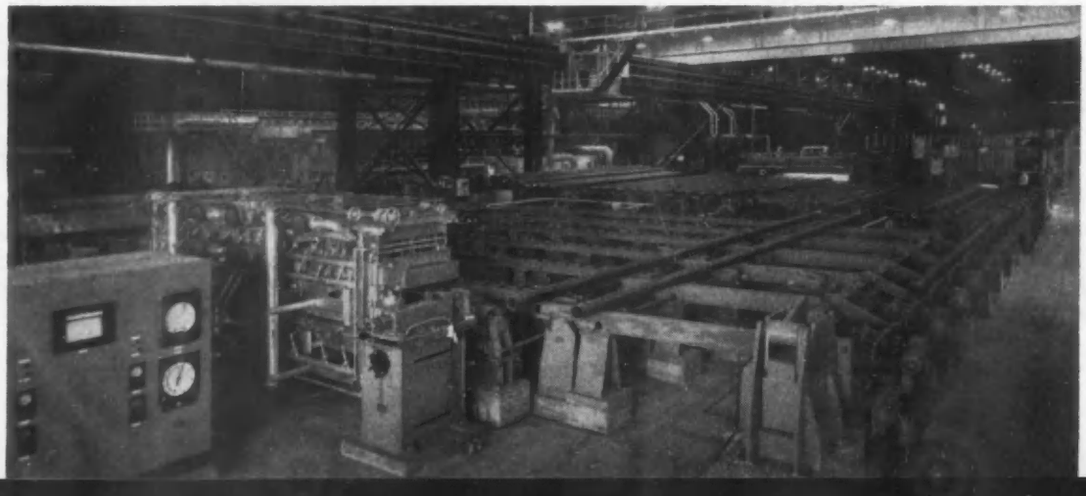
No. 3 seamless mill, Indiana Harbor, Indiana. Fully automated, ultra modern mill . . . began operating September 30. Contains world's largest Rotary Billet Heating Furnace . . . adds to our over-all capacity in both alloy and carbon casing. Offers API casing in sizes 4½", 5", 5½" and 7", in grades H-40, J-55, N-80, in ranges 2 and 3 . . . plus line pipe in sizes 4½", 5$\frac{9}{16}$" and 6$\frac{5}{8}$" O.D. in grades A, B, X-42, A106, A53 in single and double random lengths. Photo shows Rotary Furnace in foreground.

Upset finishing mill, Youngstown, Ohio. Also a fully automated mill began operations September 15. Contains a pair of automatic upsetters with attendant furnaces plus a full-length normalizing furnace for highest quality control of all products. This mill adds to our capacity for Drill Pipe in grades D, E, x-95 and in Upset Casing (Speedtite). Photo shows upsetter and control panel in foreground, normalizing furnace in left rear.



stem test indicated production of about 2500 barrels per day. Continuous oil saturation was reported at least as deep as 9100 feet. In early January, 1958, the Manifa test was reported below 9640 feet, very close to, or actually in the Arab "D" member, which produces so prolifically in other Saudi Arabian fields (e.g., Abqaiq). Even though the entire prospective section had not been thoroughly evaluated, Manifa gave every evidence of being another major Middle East field.

Aramco indicated that the "Queen Mary" would probably be kept active in the Manifa area for some time, drilling a number of evaluation wells to determine the extent of the productive area. It might be several years before the new field is put on production, not only because of the elaborate submarine pipe line system needed, but because Aramco has a surplus of Arab Zone-type crudes at the present time. Also, it might not be desirable to mix sour Arab Zone crudes with sweet Bahrain Zone crude in the pipe line from Safaniya to Ras Tanura, so that wholly separate facilities might be required to move Manifa crude to markets.

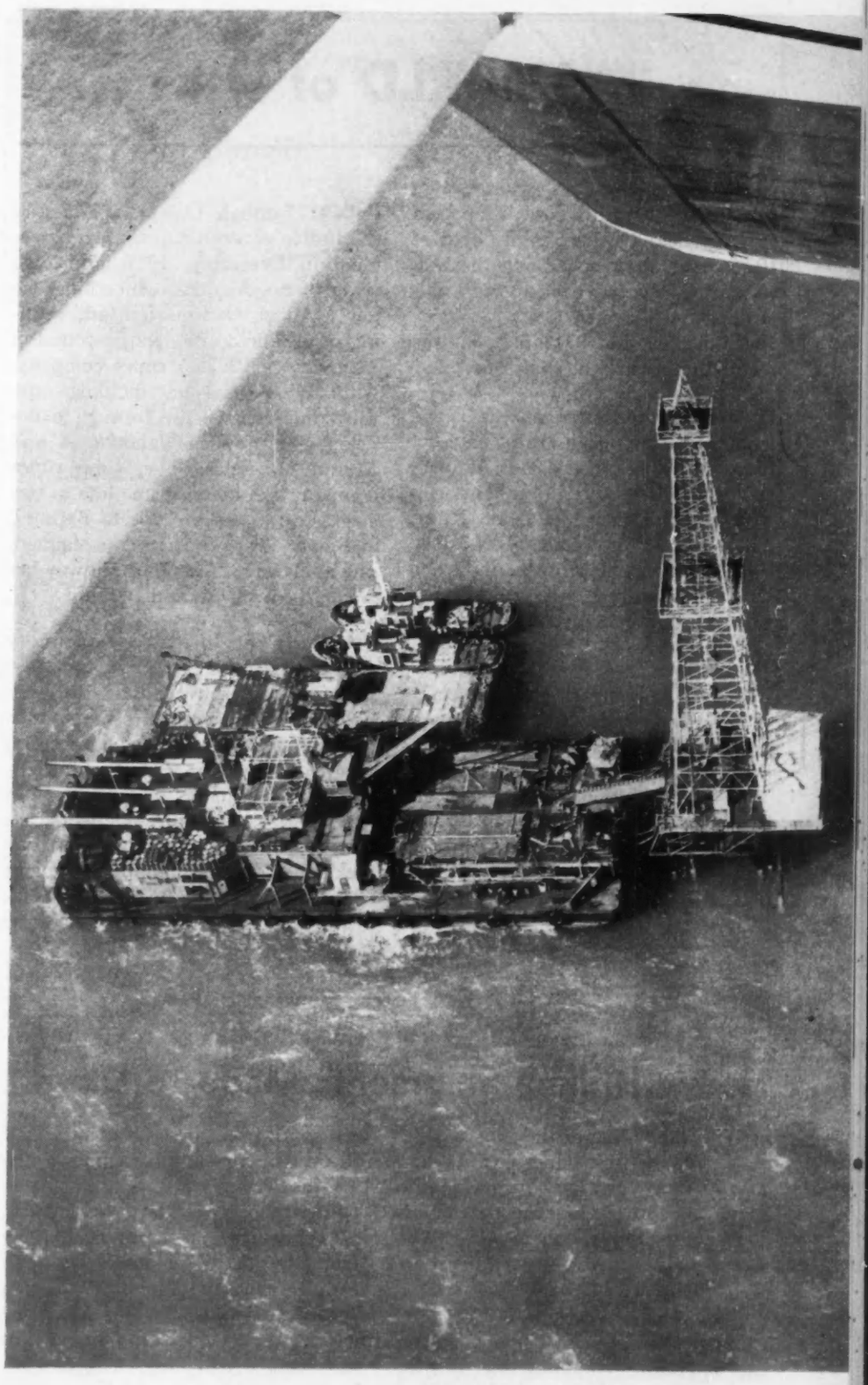
In Safaniya field, on production since mid-April, 1957 (WORLD OIL, April 1957, Page 238), cumulative production had reached approximately 19,117,000 barrels by November 30, 1957.

Elsewhere in Saudi Arabia, Aramco was drilling ahead at the Khurais 1 location, 90 miles east-northeast of Riyadh and 150 miles inland from the Persian Gulf coast. Oil had been discovered in the Arab "D" member of the Jurassic from 4755-4898 feet in mid-October (WORLD OIL, December 1957, "Khurais is Farthest Inland Discovery in Saudi Arabia," Page 181).

In early January, 1958, the Khurais 1 was reported at 9660 feet, with 7-inch casing set at about 9500 feet. More or less continuous oil shows were reported from the productive zone tested below 4755 feet, to about 6600 feet. With almost 2000 feet of varying oil saturation, there appeared to be little doubt that a major field exists at Khurais.

The Khurais test was still projected to 10,000 feet. It was planned to drill inside the 7-inch casing to the Khuff limestone of Permian age. Permian beds yield gas at Bahrain and at Dammam Field in Saudi Arabia. An oil discovery at Khurais in the Khuff limestone would be extremely important to the Permian prospects of the Middle East, particularly in Saudi Arabia.

Aramco completed 17 wells during 1957, and it was expected that about 20 wells would be completed during 1958. Four rigs were running at the start of this year, and a fifth was expected to be put to drilling during midyear. **—The End**



An aerial view of the offshore wildcat well drilled by the Arabian American Oil Company at Manifa in the Persian Gulf. At left, moored to the drilling platform is the 174-foot drilling barge "Queen Mary". On December 16, 1957, Aramco announced the discovery of oil at Manifa.

a WORLD of OIL

AUSTRIA: A depth record is reported at Wegscheid 1, where total depth of 10,390 feet was reached and the well was being plugged back to test shallower shows. WORLD OIL's 1956 survey indicated that 9711 feet was the record for Austria at that time.

FRANCE: American Overseas Petroleum Ltd. spudded its third exploratory test in the Paris Basin in January at Vernon 101, located 44 miles northwest of Paris near the Seine River. The new test, projected to 4500 feet, is on a core-drill prospect indicated by shallow drilling by Gaz de France to evaluate a once-proposed gas storage area.

HUNGARY: Hungarian sources claim that three new deposits were tapped north of Nagylengyel field. Near Babocy a deep oil deposit was found. The other locations are Solnok and Toertelje. These wells were drilled with Soviet turbine drills. Fifteen more Soviet turbine rigs were expected in Hungary before the end of 1957.

INDIA: Burmah Oil Company and the Indian government reached agreement in December, 1957, after two years of negotiations, concerning the development, transmission, and refining of prolific crude deposits found in Assam since 1953. A rupee company, with the government holding one-third interest, will be formed to develop and produce Nahorkatiya and Moran oil fields. The same rupee company will build a pipe line in two stages to move the crude to Barauni, in Bihar. Two refineries are planned, one at Barauni, the other midway between the oil fields and Barauni.

PHILIPPINES: Increased exploratory activity is planned in 1958. San Jose Oil Company has had as many as eight geological parties in the Islands in recent months, following an aerial magnetic survey in 1956. Several seismic crews will be engaged by San Jose in 1958 for Philippine work . . . It appeared in January that companies seeking oil in the Philippines might complete as many as four wildcat wells during the year.

Heavy Drilling Shipments Made to Libya

With the sailing of the Liberty ship S. S. Grifone from Houston in January, 7500 tons of rotary drilling equipment and supplies started the long journey to Libya, where Oasis Oil Company of Libya's first exploratory well will be drilled.

Oasis Oil is a wholly owned subsidiary of Ohio Oil Company and is the operating company for Libyan concessions totaling nearly 62 million acres. Ohio Oil, Continental Oil and Amerada Petroleum hold an undivided one-third interest in these concessions.

The Grifone was due to dock at Tripoli after a two-week, 7000 nautical mile trip. There the equipment was to be loaded on trucks and moved east 325 miles on a paved road along the seacoast. The caravan then would turn south from the Gulf of Sirte and roll over the desert for 75 miles to the test site.

International Drilling Company, N. V., which has contract for the well, expects to be rigged up and ready to spud the exploratory test in April. The wildcat will test a long north-south trending anticline which was mapped by Oasis Oil geologists. A seismograph survey followed and confirmed the surface work.

To combat the extreme heat in the desert land the Grifone was transporting for Oasis Oil 18 air-conditioned trailers for a mobile camp. These included 11 for sleeping quarters, a dining trailer, a kitchen trailer, three office trailers, hospital trailer and a refrigeration trailer.

The refrigeration trailer, which has 15 deep freezers and five refrigerators, was packed with meat and other perishables, and was hooked to the ship's electric power. Later it was to be hooked to the camp electric power, but it had its own engine driven generator for cooling while moving on land.

Other cargo on the Grifone included the rotary rig, with 142-foot mast, heavy duty drawworks, four diesel engines, three mud pumps, drilling mud material, cement, drill bits, skid-mounted cementing unit, three 57-ton heavy duty desert type truck tractors, heavy duty trailers and three power wagons for transporting personnel over the desert country.

The well may go as deep as 15,000 feet, seeking oil. Drill pipe and sufficient casing and tubing to carry the well to that depth and tube it if it finds oil, previously were shipped from the Port of Baltimore.

Puerto Rico Changes Rules To Encourage Exploration

Puerto Rico has announced changes in its oil and gas regulations designed to spur exploration and drilling. The major changes include:

- Extension of exclusive prospecting permits from three to a maximum of 10 years.
- Extension of lease periods from 20 to 40 years for a maximum of 70 years with renewals.
- Elimination of the checkerboard 64 hectare lease block system.
- Instead, the size of lease blocks has been increased to 1,344 hectares (approximately 3,360 acres). Lease blocks must be separated from one another by a minimum of 6,000 feet.

Puerto Rico permits all types of exploration, including seismic. A fee of $10 and a $10,000 bond are required for prospecting. Drilling is not permitted without a lease. Leases require a returnable application fee of $50 and rental at the rate of $20 per drilling unit (16 hectares) for the first year and $40 per unit each year thereafter. A $100,000 bond is required during drilling.

Oil and gas producers are eligible for incentives offered under "Operation Bootstrap," Puerto Rico's industrialization program, including ex-

emption from local taxes. Since Puerto Rico is outside the federal tax area, federal taxes do not apply. Production could be freely marketed in the U. S. as well as on the island, since Puerto Rico has free access to U. S. markets, without tariff or import restrictions.

Under Commonwealth law, the people of Puerto Rico retain ownership of any hydrocarbons that might be found to exist. In the event of an oil find, the lessee would be required to pay royalties in the island government, ranging from 5 percent to 16⅔ percent.

Discovery and Extension Wells in Canada Flowing

In the Milligan Creek area of British Columbia Union Oil Company of California and Hudsons Bay's Creek 73-G was completed for initial flowing production of 210 barrels a day through a twenty sixty-fourth-inch choke. The formation was perforated from 3,705 to 3,717 feet.

This well was an indicated discovery last year but could not be completed before the spring thaw forced suspension of drilling. Two additional wells have been spudded in, one five miles to the north and one five miles to the southeast.

In the Red Earth area of Alberta Union's Red Earth 4-20 flowed at the rate of 650 barrels a day on a formation test. This well extends the producing area of the field 6½ miles to the northeast from the nearest production. Union's next well will be spudded in five miles north of Red Earth 4-20.

Tidewater and Associates Begin Drilling in Turkey

Drilling operations have begun in southeastern Turkey at the first exploratory well undertaken by a group consisting of Atlantic Refining Company, Seaboard Oil Company and Tidewater Oil Company, with the latter serving as operator.

Located in the Mt. Bakuk area approximately 15 miles northeast of Nusaybin, the wildcat well is scheduled to test the Cretaceous section productive in Iraq to the south.

The three companies jointly hold more than 3 million acres in exploration licenses in Turkey.

International Products Company and Rimrock Tidelands, Inc. will soon begin development work jointly on IPC's large oil concessions in Paraguay. As indicated in the legend, this map shows the IPC concessions. It also shows other leases and oil fields located not far away in Bolivia and Argentina.

Two Companies Plan Drilling in Paraguay

Rimrock Tidelands, Inc., has signed an agreement with International Products Company, largest industrial firm in Paraguay, to share equally in development of an oil exploration concession in that country.

IPC owns more than 2 million acres of cattle ranges and timberland, over 65,000 head of cattle, a meat slaughtering and packing plant, can manufacturing facilities, a 200-mile railroad and a quebracho extract factory. It employs more than 5,000 Paraguayans.

The 3 million hectare (7,500,000-acre) concession consists of three tracts in the Chaco region in Paraguay, a region of rolling grass plain similar to that found in Kansas. Located in the same general area in which Pure Oil Company has announced plans to commence drilling operations, the closest western tract parallels and lies about 70 miles from Bolivian and Argentinean oil fields, which are productive in the Devonian formation.

Rimrock or a subsidiary will be the operator and drilling contractor on the Paraguayan exploration program. While local crews will be employed extensively, experienced technical personnel from the U. S. will supervise all phases of the operations.

One of Rimrock's drilling rigs in the Louisiana Gulf Coast area will be moved to Paraguay for early commencement of drilling. The drilling equipment will be moved almost entirely by water. After arriving in Buenos Aires, it will travel another 1,000 miles up the Parana and Paraguay Rivers before reaching the embarkation point for the drilling site.

The Paraguayan agreement is the third foreign negotiation for Rimrock Tidelands in the past two months. It follows closely Rimrock's purchase of Mofag Oil Exploration Company, Inc., a Swiss Corporation which owns oil concessions in Switzerland and France, and an earlier agreement by Rimrock to acquire controlling interest in Societa Olii Minerali, a Sicilian

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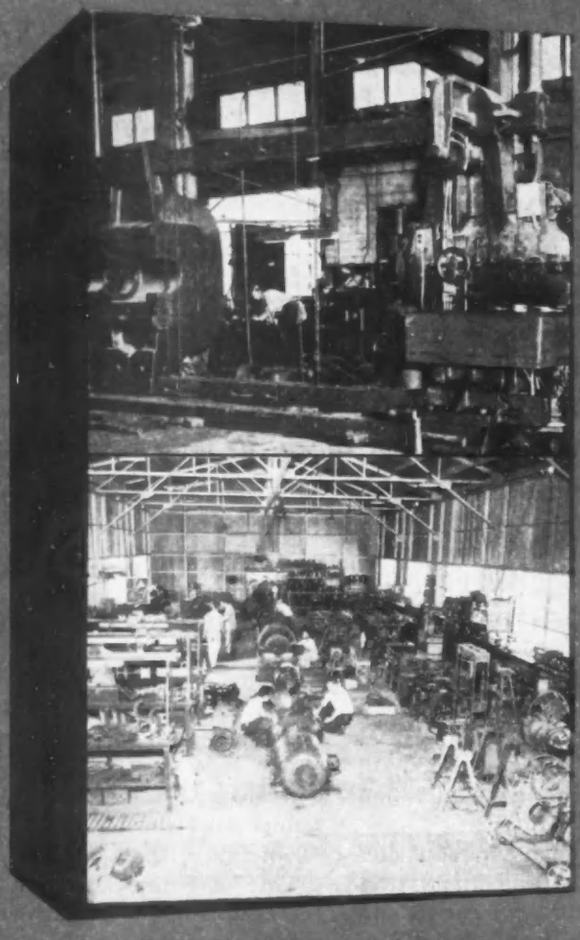

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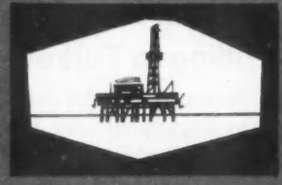
. . . and many other "special services"—engineering, research, design, fabrication, conversion and, of course, all types of construction of oil marine equipment.



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corporation which has been granted a permit for oil and gas exploration rights covering 46,330 acres on the Northern coast of Sicily.

Markets for Bolivian Oil And Natural Gas Studied

Stanford Research Institute was conducting an economic survey in January and February, 1958, to check potential markets for Bolivian crude oil and natural gas. Trans-Andean crude oil pipe lines will be considered. Potential industrial consumers in southern Brazil, Paraguay, Uruguay and Argentina will be canvassed.

If the survey results in positive findings, large crude oil and pipe line projects may fan out in almost all directions from eastern Bolivia. A surplus of crude has been found there in relation to local markets, and much more crude oil and natural gas are expected to be found and developed in the future.

Saudi Arabian Operations About Unchanged in 1957

Arabian American Oil Company completed 17 wells during 1957, as compared with 20 completed during 1956.

Aramco's total production of crude oil during 1957 was 362,121,478 barrels, an average of 992,114 barrels per calendar day. This compares with a total of 360,923,384 barrels, an average of 986,129 barrels per calendar day, during 1956.

Crude run in the refinery during 1957 amounted to 70,307,301 barrels, an average of 192,623 barrels per calendar day, as compared with 72,662,690 barrels, an average of 198,532 barrels per calendar day, during 1956.

White Eagle Group Plans Bolivian Concession Work

The Bolivian government has granted concessions totaling about 2¼ million acres to a group composed of White Eagle International Oil Co., Blackwell Oil and Gas Co. and Western Hemisphere Petroleum Corp., all of Tulsa.

The concessions granted lie in Zones 1 and 2 as designated by the Bolivian government in the central region of the country on the eastern flank of the Andes Mountains. The new holdings border on concessions previously granted to subsidiaries of Shell, Gulf and other oil operators.

White Eagle International Oil Co. is the operator for the three-company venture, and plans for development of the concessions are being formulated. Bolivia has granted about 14 million acres in oil concessions, with applications now pending for almost 10 million additional acres.

Stanvac Plans Early Work On Concession in Somalia

Standard-Vacuum Oil Company plans to begin exploration work early in 1958 on the 10,300 square-mile concession it has been granted by the government of Somalia, a United Nations mandate in East Africa. The concession covers a belt 50 miles wide, extending about 200 miles along the western side of Somalia, on the Ethiopian border.

Stanvac also has petroleum rights in adjacent British Somaliland, and has been doing seismic work there.

For about five years exploration work has been carried on in Somalia, a former Italian territory, by the Italian AGIP company, now drilling a second test well to the north of the Stanvac concession, and by the American-owned Sinclair Somal Corporation, drilling its second test well to the east.

Venezuela Faces Let-Down After 1957 Peak Output

Total crude production in 1957 in Venezuela was reported at 1,040,625,000 barrels, the first time in history that the nation has yielded a billion barrels in a year. However, a decrease was forecast for 1958, when the figure is expected to drop to 925 million barrels. This, however, would exceed 1956 production.

A total of 1860 wells were reported completed during 1957, with the total expected to decrease to 1500 in 1958.

Venezuelan Sun Oil Company, Venezuelan Atlantic Refining Company and Seaboard Oil Company announced completion of SVS Number 4 on Block 1 in Lake Maracaibo. Flow was gaged at the rate of 6063 barrels of 31.6 gravity crude oil through ¾-inch choke from perforations 9484-9582 feet in basal Eocene. About 1300 feet of oil-saturated sandstone was found. Total depth was 9687 feet.

Chili Hopes to Boost Oil Production to Equal Use

Rapid development of Cullen oil field, located in Tierra del Fuego, Chile, is being continued. A natural gasoline plant was being planned for Cullen to process casing head gas and avert waste as the field prepares to go on full production.

Discovery by Empresa Nacional del Petroleo (ENAP), the Chilean government oil monopoly, of the Gaviota oil field occurred during midyear 1957. At the year's end, two oil wells were capable of production at Gaviota, which extended the Spring Hill sand trend an additional 15 miles to the south. Five rigs continue working in Tierra del Fuego.

ENAP is now more optimistic about the oil prospects of Atacama, in the northern desert area. Geological parties have been working more than a year in Atacama, and ENAP has recently purchased seismic equipment to be used for oil exploration in Atacama during 1958.

Proposed legislation to allow concessions to private firms to develop oil production was not expected to be enacted during 1958. There was little or no popular demand for such legislation, and impending elections necessitate pleasing Chilean voters.

Pending receipt of final December figures, ENAP estimated total 1957 crude production at 4,308,508 barrels (11,804 barrels per day). Total production was 3,542,031 barrels in 1956 and 2,576,897 barrels in 1955.

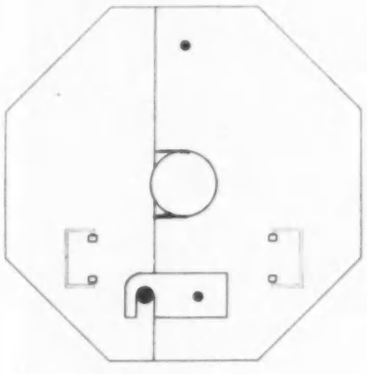
If production continues to rise at the rapid rate it has in the past few years, Chile may be able to balance petroleum needs with domestic production within five years. The prospects that Spring Hill oil production can continue to be increased at a rapid rate for the next several years are good. Production rate is rising much faster than domestic consumption, and oil imports are now decreasing.

ENAP reported the completion of 62 wells from January 1 through November 30, 1957, and estimated that a total of 70 wells were completed last year.

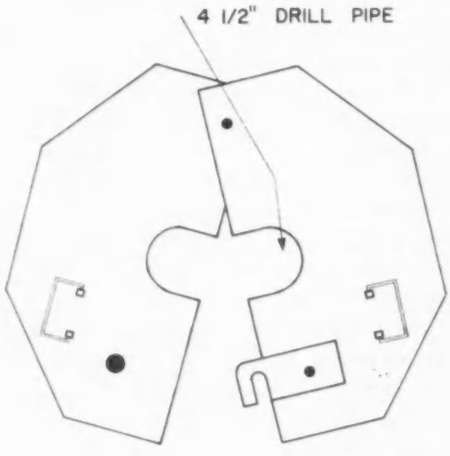
DRILLING HINTS

These How-To-Do-It Ideas Can Save You Money

$10 is paid for each illustrated acceptable contribution. Mail to The Editor, WORLD OIL, P. O. Box 2608, Houston 1, Texas.



CLOSED ON DRILL PIPE



OPEN FOR EASY INSTALLING

Fix Cover for Rotary Table During Tests

It is common practice for the hole in the rotary table to be left open or just to pack it with sacks and canvas during tests. The cover shown here will enable quick, easy installation and at the same time do a good job of keeping tools, trash and dirt out of the hole while it is being tested.

The cover shown is for a 4½-inch drill pipe, but it can be made for any size pipe. Two pieces of plate about 18 inches square are the main body of the cover. These pieces are bolted together on one end so that they overlap about 6 inches. This bolt acts as a hinge.

A latch is shaped so that it can be bolted to the top part of the cover and will extend over the lower part of the cover. A bolt is welded to the lower part of the cover so that a notch in the latch will slip around it and hold the cover together. This latch and bolt are put on the opposite end of the cover from the hinge bolt. The two pieces, the lower and upper parts, are cut to fit the size drill pipe that is being used. The two parts are then opened and the hole in each piece is extended so that a U-shaped cut is in each part.

When the cover is around the drill pipe, it will fit perfectly but when it is opened it appears to have a U-shaped cut in each piece. This will enable the crewman to put the cover around the pipe when the tests are being run.

Cascade Water Cooling Increases Heat Removal

Often it is necessary to remove heat faster than usual from cooling water around the rig. The photo shown here demonstrates how one operator increased the rate of cooling very cheaply.

The materials needed for construction are one by four, two by four and four by four inches and some extra pipe to extend the return water line. To construct the cascade, the frame members that are upright are four by four inches and are bolted to the tank. These uprights must not be placed any further apart than the length of the one-by-four piece that forms the baffles.

The upright should be in pairs, one on each side of the water tank. To these, two by fours are nailed between the uprights to form supports for the one-by-four-inch baffles. The supports should be about six to eight inches apart to give as much aeration as possible to the water as it moves through the baffling.

The one by fours which form the baffle are laid on this support so that the open spaces in the bank of baffles above is directly over the baffles in the lower bank. Care should be taken that the layers or levels of baffles are not laid one right over the other because if the layers are offset, the water

How-To-Do-It Ideas Earn Money, too!

WORLD OIL editors want how-to-do-it ideas, so your favorite short cut or invention could put money in your pocket! Write down the substance of your latest ideas and send them in with a picture or drawing of the installation . . . if accepted, $10 for each idea will be yours. Send those money-making ideas today to Hints Editor, WORLD OIL, P. O. Box 2608, Houston 1, Texas.

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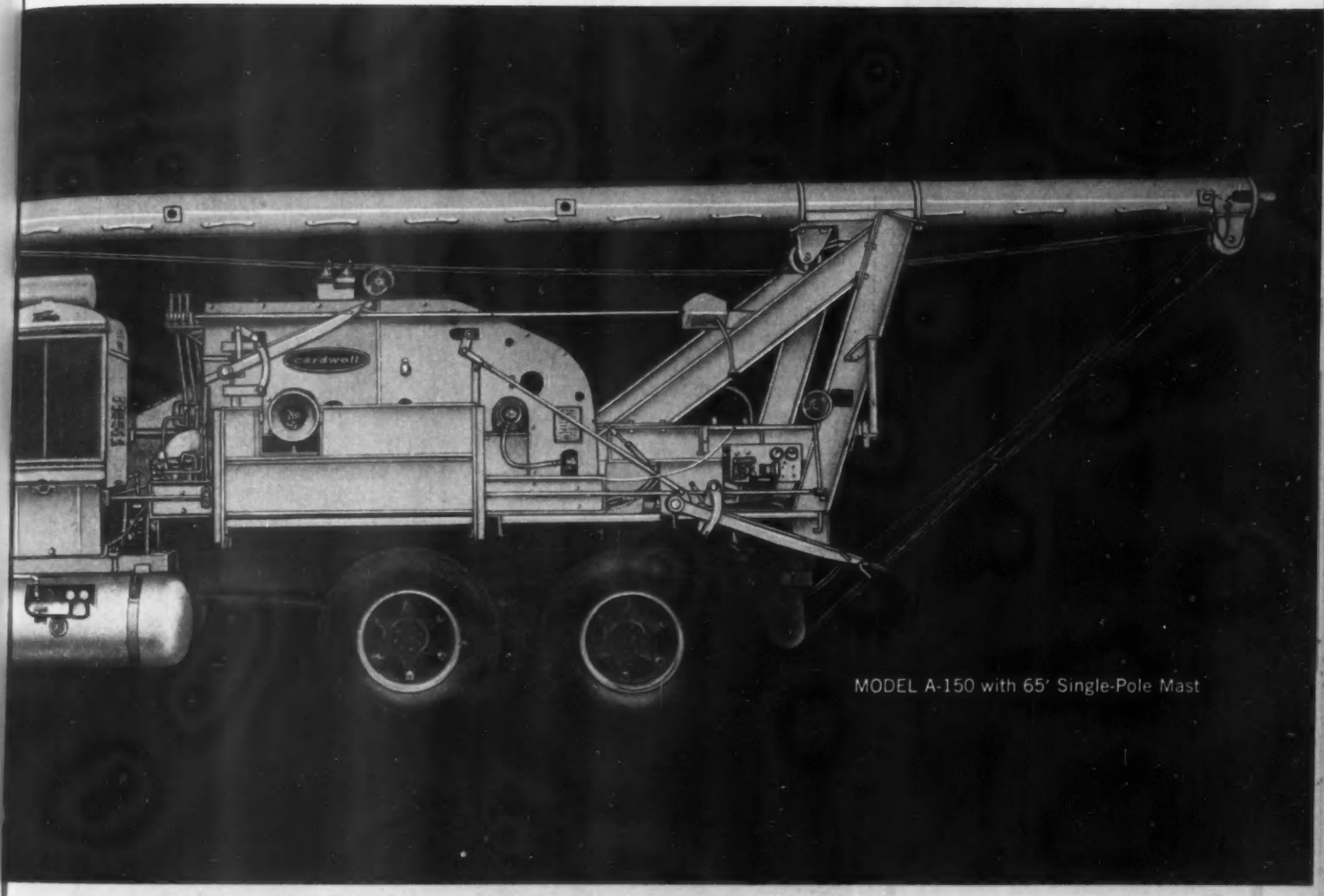
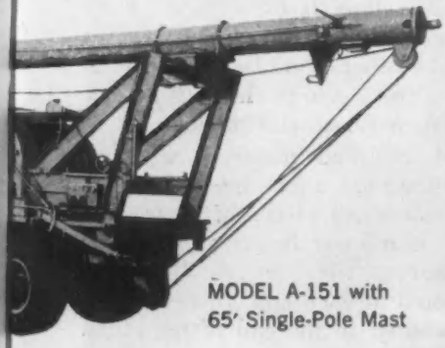


MODEL A-150 with 65′ Single-Pole Mast



MODEL A-151 with
65′ Single-Pole Mast

55-foot Single-Pole Mast
55-foot Double-Pole Mast
65-foot Single-Pole Mast
65-foot Double-Pole Mast
50-foot Non-Telescoping Structural Mast
65-foot Telescoping Structural Mast

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- Cardwell "Flex-Disc" air clutches for main and sand line drums.
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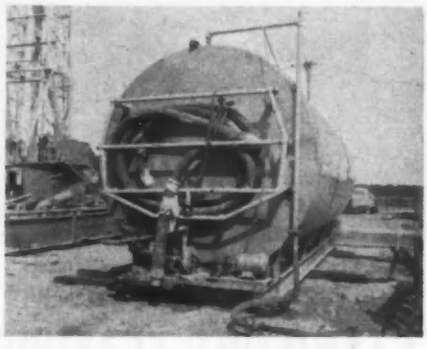
will be exposed longer to the open air, and this will greatly increase the efficiency of the auxiliary cooling system.

In order to better distribute the water over the cascade, an extension is welded to the return water line. This extension should lie directly on the top bank of baffles. Numerous perforations are put in the lower side of this water line extension to allow a little of the water to get out onto the cascade all along its length. This will serve to better spread the water over the cascade and increase the auxiliary cooling.



Attach Hose Storage Rack To One End of Water Tank

Equipping the water storage tank with a special rack can save much wear and tear on the large diameter hose; also reduces chances of the hose becoming lost or stolen when not in use. One Canadian contractor in building his cylindrical skid-base mounted water tank, built a special rack of two-inch pipe on one end of the unit.

The all-welded rack is so constructed that the two upper pipe bars can be slipped out, allowing the A-frame to lift the coil up and lay it back against the tank, holding it there until the bars can be replaced. The removable pipe bars slip through sleeves and are held in place by inserting a bolt or "hairpin" of welding rod through a hole in each end. By making the bottom of the rack dish-shaped as shown, additional support is given the hose and reduces sharp bending or kinking.

Any danger of excessive weight causing the rack to pull away from the tank, or damaging the tank shell, is eliminated by welding the two-inch horizontal stulls to 12-inch plate pads, then welding the latter to the tank shell.

Quickly-Built Pipe Clamp Holds Lines Around Rig

The water lines and mud hopper discharge lines around a rig are often subject to pulsation, and it is necessary to anchor them in some manner.

A simple effective means of holding these lines is by a pipe clamp. The clamps must be of light weight and be easily put in place or removed. The picture above shows how one contractor solved this problem.

The required materials are two bolts and nuts, a length of angle iron, and two small pieces of plate. The angle iron must be long enough to lay across the lines and be well anchored at each end. In this case it is anchored to the end of the tanks.

Semi-circular segments are cut, from the angle iron, that fit the pipes that are to be held down. Anchor holes are burned in the angle iron. A piece of scrap plate is welded to the mud tanks or other solid mounting for each end of the angle iron clamp. Anchor bolt holes are burned in the scrap plate anchors and are just large enough to allow passage of the anchor bolts. This will allow easy insertion

Lifting heavy beams for steel-skeletoned skyscrapers, over the heads of pedestrian and vehicular traffic, calls for careful loading — with safe slings, stout wire rope and a crane that's securely guyed with steel cables. Structural steelworkers practice safety because they know that . . .

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Today, taller buildings, bigger bridges, deeper oil wells, greater construction projects require stronger, safer wire rope. And equipment operators know that when you buy "bargain" rope you're heading for headaches, trouble and expense. So don't bargain with safety. Buy wire rope on the basis of *quality*. Buy Wickwire Rope.

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LOOK FOR THE YELLOW TRIANGLE

For more data on advertised products, use Readers' Service Cards, last page.

Tips on Mud Valves for Toolpushers . .

Freddie Machacek gets ready to open one of the dozens of Mudwonder valves on the fill-up line of Rig #4.

MUDWONDER Ideal for Versatile Service

by Freddie Machacek, Toolpusher, Rig #4
B.B.M. Drilling Company, Midland, Texas

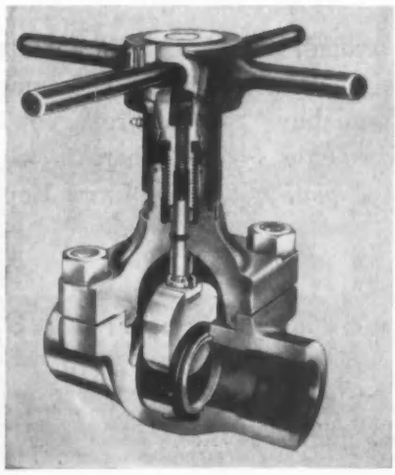
ABOUT two years ago I put a *Mudwonder* valve on our fill-up line just to see how it would make out. I soon found that *Mudwonder* worked fast and easily, without binding, even while bleeding off the line at 1600 lbs pressure. It did so well I tried more *Mudwonders* on the tough job of mud pit service—and they were so successful I've standardized on *Mudwonder* ever since!

Valves on mud guns and jets take a terrific beating, but we've had very little trouble with *Mudwonders.* As a matter of fact, our first ones are still in service; we replaced the stem packing on one valve—that's all! Because replacement parts are so easy to identify, we never have any trouble getting the exact part we need. In fact, the valves are designed to use the same seat and gate for both pressure classes.

When we have to dress a *Mudwonder,* the job can be done without disturbing any connections. The valve is out of service only about 10 minutes, start to finish, regardless of size. Another thing—they never sand up. Bob Lawrence, Edward *Mudwonder* Representative, says this is because the design causes the mud to flush the bonnet automatically.

Mudwonder valves are available in 2", 3" and 4" sizes; with screwed or flanged ends; rated at 2000 psi WP (4000 psi test) and 3000 psi WP (6000 psi test). See your favorite oil field supply store for complete information, or write Edward Valves, Inc., East Chicago, Indiana, subsidiary of Rockwell Manufacturing Company.

Mudwonder cut-away view shows the one-piece seat insert, with Buna-N molded integrally over steel wear rings; chromed gate with "T" slot connection; separated stainless stem and double thread construction.



(Adv.)

DRILLING HINTS . . .

or removal of the bolts when the clamp is being installed or taken off. When the anchor bolts are passed through the holes in the scrap plate anchor and the angle iron clamp, the angle iron is held down firmly to the pipes to keep them from moving excessively.

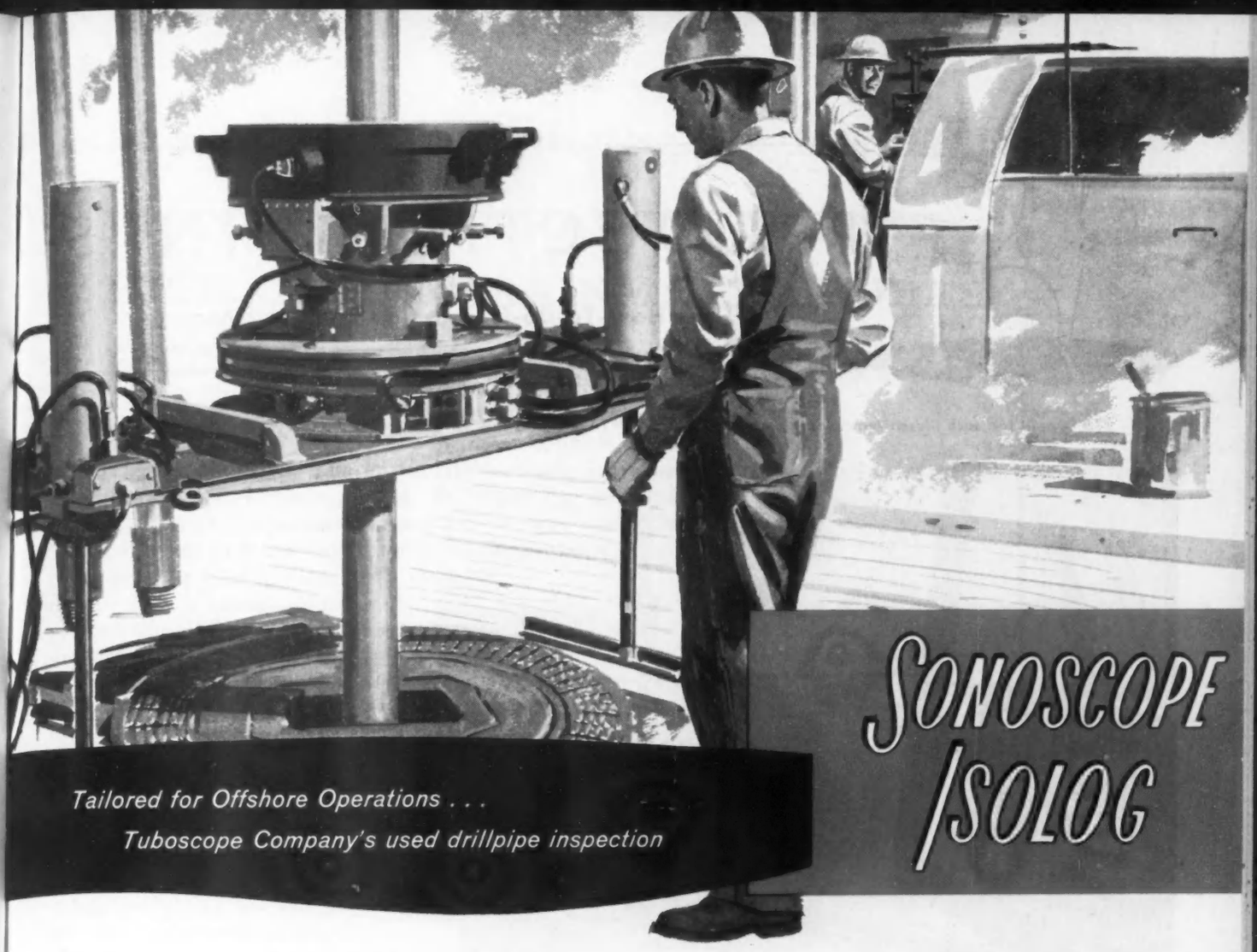
Pipe Union Anchors Rail To Fixed Section on Truck

A pair of salvaged two-inch unions provides assurance for one contractor that the low guard rails on his light flat-bed tool truck will not be bounced off and lost while traveling rough roads frequently encountered in his area. Shopmade, the rails consist of two horizontal bars, the upper one being of two-inch pipe and the lower of angle iron; expanded metal being welded over the area between them. They are equipped with short stakes which fit the normal flat bed stake holes.

At the point where the removable rail section joins the fixed rail behind the cab, a pair of matched, reasonably aligned two-inch threaded nipples are welded, one on each rail, and the two-inch union installed. They can be salvaged, though servicable unions are preferable since the threads are sufficiently worn to permit easy alignment and spinning up by hand.

This type of connector, which can be of any size depending upon the size pipe used in the rails, is installed or removed easily, takes up no extra space and requires no wrenches during normal operations. It is of particular value where perhaps several such guards may be used on a truck, and where, for reasons of flexibility, one or more pairs may have to be removed to suit immediate loading conditions.

For more data on advertised products, use Readers' Service Cards, last page.



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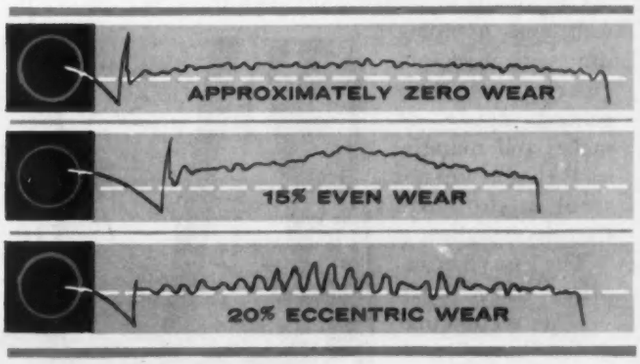
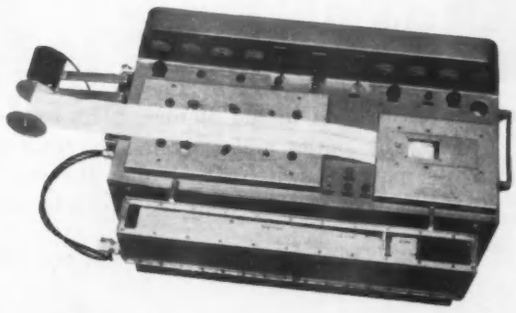
Tailored for Offshore Operations . . .
Tuboscope Company's used drillpipe inspection

Tuboscope's Isolog® measures and records wall thickness of drill pipe as it is being pulled from the hole. As the pipe is being pulled, a gamma ray beam is continually directed diametrically through it. Variations in pipe wall thickness cause corresponding variations in the amount of gamma rays passing through the pipe to a scintillation counter. These variations result in corresponding variations in the signal transmitted to the recorder, indicating relative wall thickness.

The standard Sonoscope® detects and records inside and outside surface discontinuities as the pipe is being pulled from the hole. When performing an Isolog-Sonoscope inspection, the operator, by scanning the logs being produced, quickly determines the effect of defects and wall thickness reductions on serviceability of the pipe.

- Measures wall thickness while coming out of the hole
- Detects fatigue cracks, corrosion, pits, cuts, etc.
- Detects internal structural conditions





Tuboscope COMPANY

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PRODUCTION HINTS

These How-To-Do-It Ideas Can Save You Money

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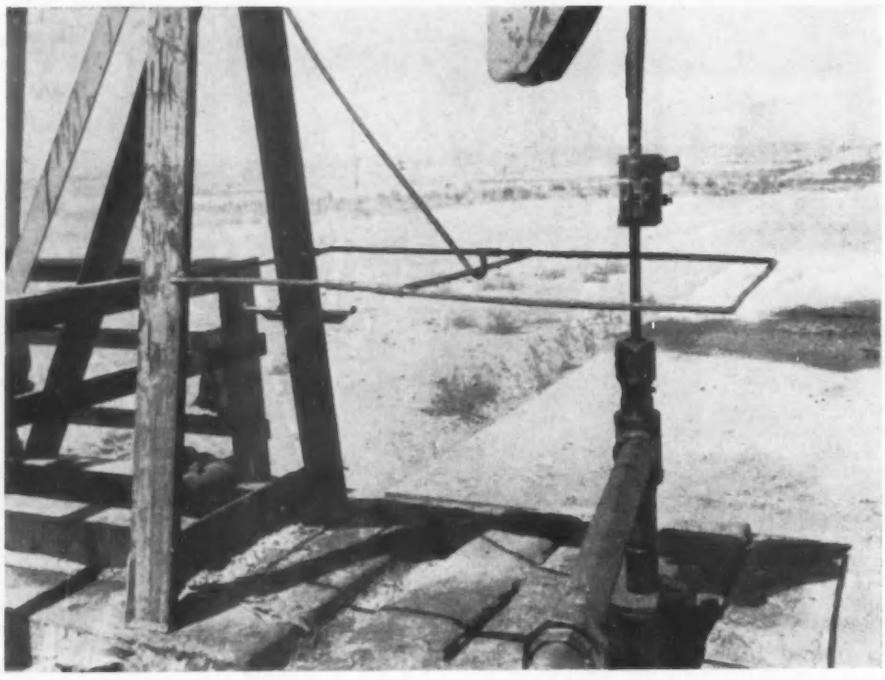
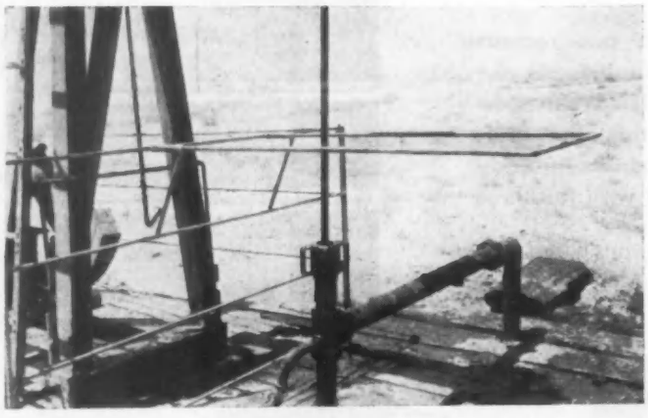


Make Guard of Sucker Rod Material

Protection is provided from the moving horsehead as well as preventing anyone from walking between the well and pumping unit with a rectangular, demountable guard made of sucker rod material or lighter-weight steel as shown in the picture above.



The guard comprises three parts:

1. a rectangular section hinged, with the aid of pipe sleeves welded to the sampson post, to the front of the unit;

2. a sucker rod hook, attached to the unit near the saddle bearing, which supports the rectangle, and

3. a U-shaped section which forms the guard, the two ends of this member projecting and being supported by pipe sleeves welded to the sides of the rectangle.

When access to the tubing head is necessary, the U-shaped member is pulled out and the hook disengaged, allowing the rectangle to fall back out of the way and leaving maximum working area around the well.

A similar but self supporting guard of a rectangular shape is pictured in the second picture. This guard may be installed using only the sockets attached to bracketed supports on a guard rail extending across the front of the pumping unit. Additional bracing may be required if the guard rails should prove to be excessively limber, depending upon the distance involved in the overhang of the guard.

Either type guard pictured can be adapted easily to any conventional pumping unit and can be modified to suit the particular desires of the operator. For the most part, salvaged sucker rod material or reinforcing steel, plus short lengths of small diameter pipe serving as sleeves, constitute the principal materials required. In many instances, the greater part of the welding can be done in the shop; these shop-fabricated parts being more or less standard, permitting them to be made up in quantity and thus cutting the cost per unit.

Mercury Switch Provides Self Shut-Off Operation

One operator has obtained automatic shut-off control when emptying a salt water disposal tank by pump to a salt water injection well by employing a mercury switch on the dump valve at the tank outlet. This principle could also be employed on any pumping operation where controlled shut-off is desired. The dump valve, as shown in the picture, is set at the tank outlet and is connected with a mercury switch fitted onto the regulator arm. The mercury switch breaks

A new concept for separating and **METERING** *of*

VISCOUS, LOW-GRAVITY CRUDES
HIGH GAS ENTRAINMENT CRUDES
EXTREMELY HIGH FLOW RATES (to 50,000 BPD!)

The Rolo HI-CAP Metering Separator consists of an oil-gas separator and parallel volume-type oil meters, all in one vessel. Its metering principle offers significant advancement over previous units, enabling previously difficult or impossible conditions to be handled with ease.

HOW IS HIGH CAPACITY ACHIEVED?

Parallel dump-type meter chambers **fill as fast as the incoming flow rate, there being no gravity flow through restrictive lines and valves.** And there's no time-consuming accumulation of oil while a meter is dumping . . . parallel meter chambers **continuously** meter **all** oil produced.

VISCOUS CRUDES?

Low gravity, viscous crudes have always presented a metering problem, **but no longer** . . . With the HI-CAP, there's nothing to slow down meter filling and discharging, and even viscosities of 100,000 SSU and higher are no problem to the HI-CAP.

HIGH GAS ENTRAINMENT?

The problem of high, variable gas entrainment in crude is answered by weight metering (as opposed to volumetric metering). Precision-engineered instrument systems (electric or pneumatic) are available on all HI-CAP units to meter oil by weight (in addition to volume). In this way, foamy or other high-gas-content oils are **accurately** metered by the simple attachment of these instruments. **(See description at right.)**

Now, the advantages of oil metering can be applied to extreme conditions . . . there's a HI-CAP unit, Type A or B, applicable to **your** conditions. Available in all diameters through 60" and larger, in vertical or horizontal vessels (latter available on trailers), and with various size valves.

Write for further information. **For an immediate proposal,** advise: maximum flow rates, gravity, viscosity, separation pressure, preference for vertical or horizontal vessel and other applicable information.

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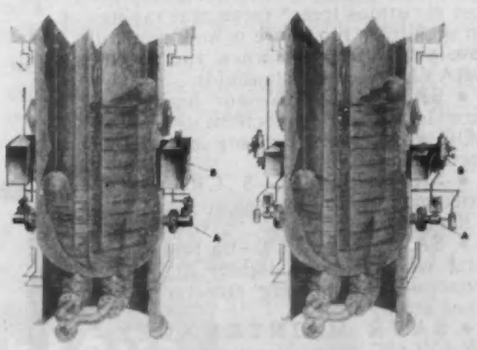
AVAILABLE WITH WEIGHT METERING INSTRUMENTS

Available as options on all HI-CAP units are compact electric or pneumatic instrument systems to allow metering by weight principle. Metering by weight is especially applicable to crudes of high, variable gas entrainment.



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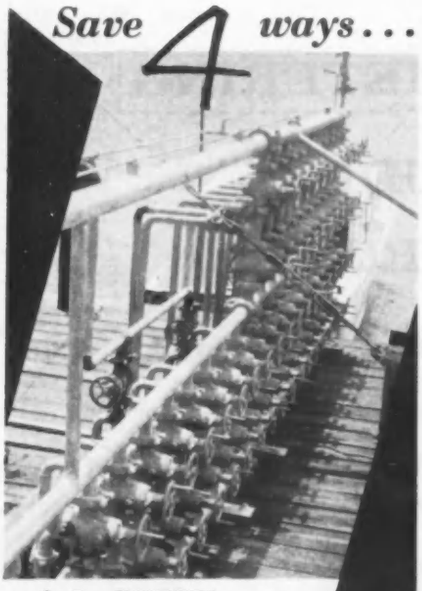
PRINCIPLE:

Two differential pressure sensing and transmitting devices (A) are provided, one for each meter section. These devices respond to changing liquid heads in the meter sections. As a meter section fills, a signal proportional to the increasing liquid level is transmitted. This signal positions a servo device in the receiver (B), which drives a pulsing device calibrated to send a pulse for every barrel of liquid. These pulses are totalized by a counter or can be recorded or remotely transmitted.

When a meter section is discharging, a clutch in the servo system eliminates pulses from that meter. Thus, only incoming liquid is counted.

A special calibrating device (graduated in degrees API) is standard; with one simple adjustment, the system can be set in infinite increments for any gravity between 5° and 50° API. (For automation, this adjustment can be made automatically on signal from test programmer.)



with NEW
GRAYLOC®
Fitted Manifolds

Features that make GRAYLOC the most widely used connection in 30,000# test christmas trees* mean real savings on manifolds too. Here is how you will save year after year when you specify GRAYLOC-fitted manifolds.

- **SAVE MONEY**—for high pressure leakproof connections — GRAYLOC costs less than any other connection.
- **SAVE SPACE**—5 GRAYLOC-fitted valves occupy no more space than 4 flanged valves.
- **SAVE WEIGHT**—up to 1/3 less total weight means lighter and more economical supporting structures, yet more strength.
- **SAVE MAINTENANCE**—GRAYLOC connections are leakproof initially and the pressure aided GRAYLOC seal keeps them leakproof—reducing inspection and repair costs to a minimum.

Gray Tool Company engineers are ready to show you just what these savings mean to you, whether your needs are for a manifold, a christmas tree or a single connection.

***There are more 30,000 psi GRAYLOC christmas trees in service than all other makes combined.**

For additional information, write or 'phone GRAY TOOL COMPANY.

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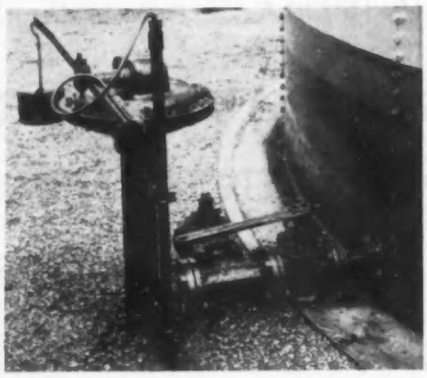
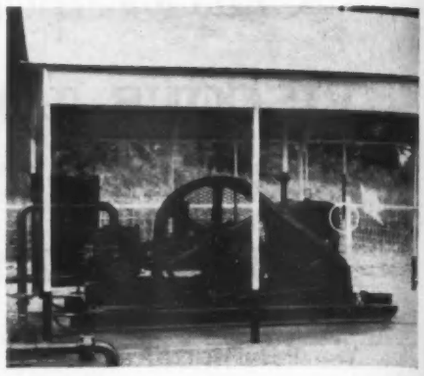
Edmonton, Alberta, Canada

MEXICO
Vical, S. A.
Av. Insurgentes SUR
1774, Mexico 20, D.F.

PRODUCTION HINTS . . .





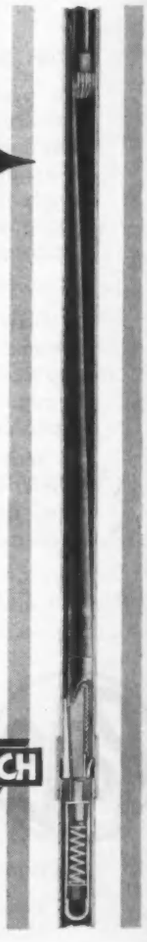
contact with the magneto on the pump engine, shown in the picture.

The dump valve is set at a predetermined level. When the tank volume is pumped down to this level, the decrease in hydrostatic head actuates the valve which causes the regulator arm to lower the mercury switch breaking contact in the line connected to the magneto on the pump engine. The pump shuts off and therefore the operation is automatically controlled. The insulated line shown in the picture with the dump valve is connected to the mercury switch and run through a ¾-inch line which serves as a conduit, shown in front of the dump valve. The conduit is installed underground to the pump shed where it is fabricated into the shed roof and then extends downward to near the magneto on the pump engine, as illustrated by the circle and arrow.

The ¾-inch conduit line is attached to the four-inch vertical riser underneath the dump valve by two tee-shaped pieces of scrap metal, welded to the riser and circular rings enclos-

KINZBACH WHIPSTOCKS

POSITIVE SETTING . . .
SAFE DRILL-OFF



You set your Kinzbach Whipstock at desired depth and position with absolute confidence of positive grip. Trigger assures that whipstock will be set so window will always be in only one joint of pipe. Concave section pivots on one direction hinge above slip section so upper lip always lies against pipe for safe passage of working tools; cannot be hinged into obstructing position.

Whipstock safely, where you want to, and in proper direction with Kinzbach Whipstocks. Available in all popular casing sizes.

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ing the ¾-inch conduit protection line.

The mercury switch mounted on the dump valve regulator arm has worked very satisfactorily on this modern salt water disposal system. The principle could easily be adapted for convenient use in many other phases of field production operations.

Build Accessible Tool Rack Behind Pumper's Truck Cab

One company has provided convenience for the pumper and easy accessibility to frequently used tools on a lease truck by having the tools mounted at a convenient accessible location. This method has eased the pumper's duties and also minimized loss of tools and other equipment.

A convenient tool rack on the back of a cab with a tool box for small hand tools provides a place for equipment. The pumper can tell at a glance whether he has collected all the tools after the job.

The rack can be constructed by welding a ledge about 14 inches wide across the back of the cab with the small tool box mounted on top at the left side. As shown in the picture, a hand winch is mounted in the center with a block and chain for loading heavy equipment. The water can is mounted on the right side and a well for an oil can is mounted directly behind it. Two-inch pipe nipples are welded to the edge of the ledge. These make convenient places to hang larger tools such as pipe wrenches, cheaters, hammers, crescents, gage lines etc.

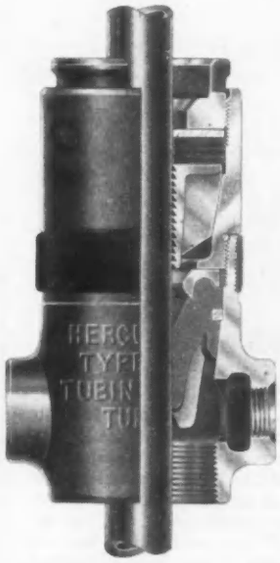
The tool rack ledge is made from scrap metal and spot-welded to the bed of the pick-up. The tool box can also be made from scrap metal and spot-welded to the ledge.

Guards Insure Safe Work On Pumping Unit Beam

Safety and improved working efficiency are combined in the hand rail and special enclosed ladder which one company installed on the beam of one of their very large pumping units. The hand rail, made of sucker rod material, assures much greater safety for

You get the most ECONOMICAL SERVICE from...

HERCULES TUBING HEADS

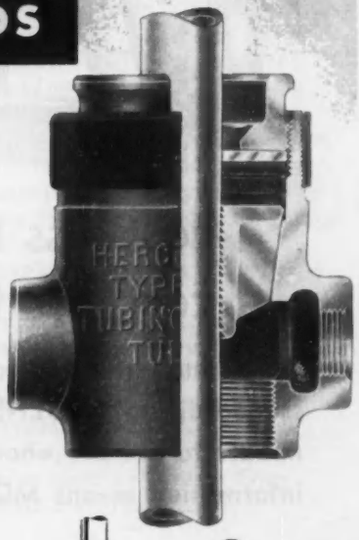


"TYPE J-5" TUBING HEAD

Ideal for flowing or pumping wells or for well servicing and repressuring projects. Will suspend 2" tubing to 5½" casing up to maximum of 180,000 pounds. Head is full-opening; constructed of pressure cast steel tested to over 4,000 psi. HERCULES original overhead packing arrangement and hinged slips facilitate installation and servicing. HERCULES Neoprene Tubing Stripper (2"-2½"-3") may be used in this head on wells flowing intermittently or to wipe tubing. Equipped with safety threads.

"TYPE J-5-S" STRIPPER TUBING HEAD

The dual purpose "Type J-5-S" Stripper Tubing Head is basically a "Type J-5" Tubing Head with a bowl (top section) screwed into the packing nut thread. The hinged slips, packing and packing nut are installed in the bowl (top section) with the tubing stripper in the body (lower section), thus permitting tubing to be run-in or removed under pressure. Test pressure is the same as the "Type J-5" Tubing Head.



HERCULES TOOL Company

Available through all supply stores

"MANUFACTURERS OF OIL FIELD EQUIPMENT SINCE 1924"

GENERAL OFFICES AND PLANT TULSA, OKLAHOMA

30 Church Street, New York 7, N. Y.

Export Representative: Oil Field Equipment Co., Inc.,

For more data on advertised products, use Readers' Service Cards, last page.

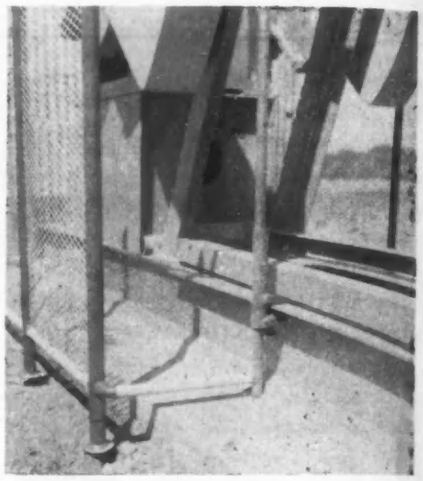
the man in getting to either end of the beam; also permits him to walk instead of sitting down and "hunching" his way while at the same time carrying grease gun and tools.

At the horsehead end a short ladder, equipped with cage and floor, was welded to the side of the beam. This greatly simplifies access to the sucker rod rotating and adjustment device rod. It also permits safer and easier work when the horsehead is unbolted and re-installed whenever the well is pulled.

Flexible Sleeve Device Adapts Easily to Unit

A method of attachment that permits using a single design of guard on a variety of sizes or types of pumping units saves installation costs for a Canadian operator. The system requires no burning of holes or welding on the unit base, a feature that eliminates introducing possible weakness in the structural members; also eliminates need of a welder for custom fitting to the particular unit.

Key to installation, and visible in the photograph, is a pipe sleeve which, when installed on the inner leg at each end of the guard, permits attachment to any desired point on the I-beam base. Welded to the lower end of the sleeve are two parallel lugs, the lower one being drilled and tapped for a heavy square-head machine bolt. Distance between these lugs is such that it will accommodate the web thickness likely to be encountered on most pumping unit bases. After the guard has been spotted and the outside legs supported by either the concrete slab or pieces of pipe set in concrete alongside the slab (as pictured), the machine bolt on each clamp is tightened. Although the guard then is solidly positioned, it can be removed easily and quickly when necessary to service wrist pin bearings and the gear box.



Ability to fabricate a number of such guards in the shop for later installation in the field, and without further recourse to the services of a welder is one of the chief advantages of this type unit.

Keep this fact pasted in your hat . . .

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. . . cost less to install

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. . . these are but two of many important reasons for standardizing on JENSEN JACKS. Don't wait another minute to get the whole picture. It's a case where more information means MORE MONEY *for you!*

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How-To-Do-It Ideas Earn Money, too!

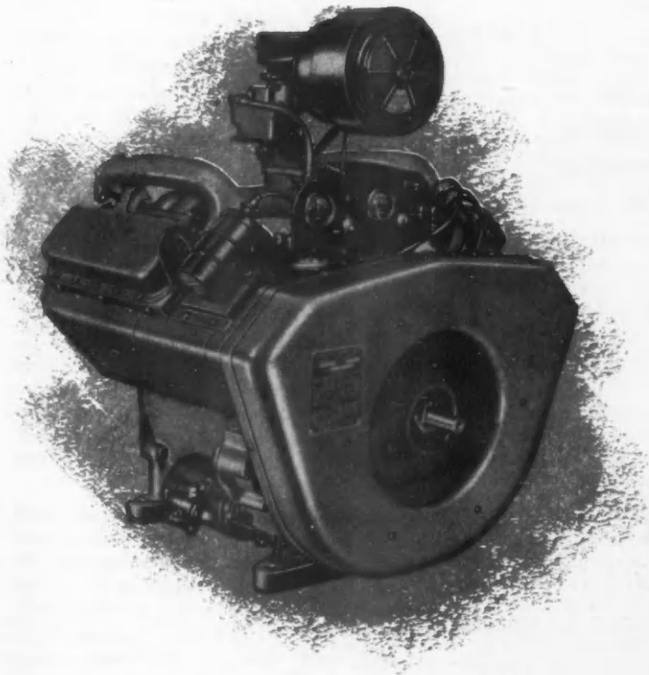
WORLD OIL editors want how-to-do-it ideas, so your favorite short cut or invention could put money in your pocket! Write down the substance of your latest ideas and send them in with a picture or drawing of the installation . . . if accepted, $10 for each idea will be yours. Send those money-making ideas today to Hints Editor, WORLD OIL, P. O. Box 2608, Houston 1, Texas.

NEW...

POWER-PACKED CHAMPS OF THE AIR-COOLED ENGINE FIELD

by HERCULES

HERCULES C2-90D
Design by Lycoming
35 HP; 274 pounds, dry



HERCULES CV4-180
Design by Lycoming
70 HP; 463 pounds, dry

No other industrial air-cooled engines pack the horsepower/pound of these two- and four-cylinder models. Modern design gives them 40-90% more HP per cubic inch displacement. Add to this high usable power, the economy of these engines . . . up to ⅓ in fuel savings over competitive engines . . . and you've got an unbeatable combination for your equipment power or power-unit applications.

The Hercules industrial air-cooled engines of Lycoming design have the dependability and endurance for which the Lycoming name is famous in aircraft engines. Crankshaft design is oversize and all bearings are of the replaceable type. With overhead valves, "top-overhaul" is fast and simple on these Hercules units; in fact, complete engine rebuild can be accomplished without removing the engine from its mountings.

Lubrication is by force-feed system with the oil fed from the crankcase to the engine's moving parts by gear-type pump through a pressure relief valve.

Available as engines or complete power-units, with accessory equipment to match service conditions, these engines have been refined by Hercules and are backed by Hercules reputation for quality, stamina and engineering excellence. Prompt service is available through Hercules world-wide distributor organization.

For further information, write Hercules Motors Corp., Dept. 100, Canton 2, Ohio. Other Hercules engines from 5 to 475 HP.

HERCULES

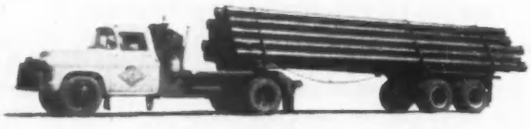
HERCULES MOTORS CORPORATION
Canton, Ohio

For more data on advertised products, use Readers' Service Cards, last page.

Congrats and $25 to S. G. McNatt, General Delivery, Bowman, North Dakota, for this quip.

Every day sees load after load of Lone Star API casing, tubing and line pipe leave the big Lone Star plant for the field. Constant research and the nation's most modern steel and pipe-making facilities are Joe Roughneck's guarantees that Lone Star pipe has what it takes. Depend on Lone Star . . . the oil country's steel mill.

Neighbor, wherever you are, specify Lone Star and we both get a good deal.



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COMPANY

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BOOKS

OIL AND GAS DEVELOPMENTS IN KANSAS DURING 1956, University of Kansas Publications, State Geological Survey of Kansas, Bulletin 128, by E. D. Goebel, A. L. Hornbaker, P. L. Hilpman and D. L. Beene.

The Kansas petroleum industry hit some new records in 1956, including crude oil and natural gas value and production. Because of an increase in the production of crude oil and natural gas, the dollar value of these resources exceeded all previous records.

Eighty-two Kansas counties have produced or are producing oil or gas, two more than in 1955, Rawlins County was added with the finding of oil in the Lansing-Kansas City group, and Wallace County with new gas reserves in Morrowan strata.

Four maps and numerous tables are included in the bulletin.

REVIEW OF GEOPHYSICAL ACTIVITY IN KANSAS THROUGH 1956, State Geological Survey of Kansas, Bulletin 127, Part 1, University of Kansas Publications, Lawrence, Kansas, by William W. Hambleton and Daniel F. Merriam.

The object of this report is to serve as a guide to other geophysical studies in Kansas by collecting the published literature dealing with the geophysical activities in Kansas.

Much of the information pertaining to these activities have been kept secret because of the possible value to is owner. A summary of exploration activity is included in order to emphasize the magnitude of the geophysical industry and its importance. Reference is made to magnetic, gravity, electrical, seismic and radioactive studies, but not to bore-hole investigations or geochemical studies.

PETROLEUM REVIEW, BORDEN COUNTY, TEXAS, Phifer Petroleum Publications, P. O. Box 20,024, Houston, $10.

The review was compiled by Robert L. Phifer from the records and hearing files of the Railroad Commission of Texas. The new book offers a complete history of the discovery, development and production of 37 fields that have been discovered in the county since 1948.

The field histories in the 82-page book include the discovery well and important information about it; the development lists all surveys (including block and section numbers), known subsurface structure data, a typical set of formation tops, deepest well, field rules and regulations, number of wells, all operators and market outlet; production is given by years and cumulatively listing the number of producing wells at the end of each year. The 35 illustrations include a county map with the fields in color, three charts for quick reference, subsurface structure maps of various fields and electric logs of many discovery wells.

For more data on advertised products, use Readers' Service Cards, last page.

What's Happening

among MEN in the INDUSTRY

T. C. Brunson has been named assistant secretary and assistant treasurer of **Humble Oil & Refining Company.** He succeeds **Ben P. Barrett,** who retired after 36 years with the company. Brunson, a veteran of 33 years with Humble, served as cashier in the Banking division of the Treasury department before his promotion. In his new job, he will be in charge of the Payroll division of that department. **Otto E. Roesler,** former assistant cashier, will assume the cashier's post left vacant by Brunson's promotion. He has been with Humble 38 years.

•

The Standard Oil Company (Ohio) has elected **Charles E. Spahr** to be president of the company succeeding **Clyde T. Foster,** who continues as chairman of the board and chief executive officer. Spahr has been executive vice president and Foster both chairman and president. Spahr has been with Standard of Ohio since 1939. He was elected the executive vice president in February, 1955, and a director in April, 1955.

•

E. J. Deu Pree succeeded **T. B. Flood** as vice president and general manager of production of **The California Company.** Flood, who was also a director of the company, retired from Calco after more than 37 years of service. He had been vice president for over 15 years. Deu Pree, formerly assistant manager of Production, in his new position will direct Calco's production activities which cover a wide area from the Rocky Mountains to the Gulf of Mexico.

E. J. Deu Pree

•

T. L. Owen, a veteran of more than 26 years in drilling, has been promoted from tool pusher to superintendent of the Land Drilling division of **Rimrock Tidelands, Inc.** Simultaneously, **G. D. Murray** was appointed superintendent of the Marine Drilling division. In his new capacity, Murray will be in charge of Rimrock's four offshore drilling rigs now operating under contract on self-contained platforms in the Gulf of Mexico, as well as the company's two new barge mounted rigs which will begin operations later this year. Tool pusher on Rimrock's Rig #10 at the time of his present promotion, Owen became associated with the company in June, 1956, when it merged with Trans-Tex Drilling Company.

B. P. Eastin

W. F. Bates

W. F. Bates has been named area production manager for **Shell Oil Company's** west of the Rockies operation. **B. P. Eastin,** whom Bates will replace, has been appointed manager of production research for Shell Development Company's Exploration and Production Research division in Houston. Bates, until his recent promotion, has been assistant to Shell's Pacific Coast area vice president. Eastin, production manager for Shell's Pacific Coast area, has held a number of field and administrative jobs with Shell in Ventura, San Francisco, Los Angeles and Long Beach, Calif., and Casper, Wyo.

•

Henry H. Neel has been appointed manager of exploration of **Tidewater Oil Company.** Neel moved up from his former assignment as manager of foreign exploration. In his new post he is responsible for planning and coordination of both foreign and domestic exploratory programs for Tidewater.

•

Horace C. Flanigan, chairman of the board of Manufacturers Trust Company, has been elected a director of **Union Oil Company of California.**

•

Geophysical Service Inc. has announced two executive appointments in affiliated companies. **G. J. Kohler, Jr.,** has been appointed vice president of Geophysical Service for geophysical operations in Latin America. **Ray H. Wright** has been named vice president of Geophysical Service International Corporation for Canadian geophysical operations. Kohler is assigned to GSI's headquarters at the Exchange Bank Building in Dallas. Wright directs the firm's Canadian operations from offices in Calgary, Alberta.

•

Z. C. Ambrose was named president of **Associated Oil & Gas Company.** He has been assistant president of the company since August, 1954. **H. J. Mosser,** who has been president of Associated was advanced to chairman of the board of directors. **D. C. Bintliff,** formerly executive vice

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M. M. Kinley Company, Licensees

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C. A. White 3-5264
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C. A. White ..... EM 5-3833
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Horne Well Service Co. 3-5396
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KILGORE, TEXAS
Davis-Kemp Tool Co., Inc. 5541
LAFAYETTE, LOUISIANA
Assoc. Eng. & Eqpt., Inc. ..... CE 5-6770
LIBERAL, KANSAS
Rainbo Service ..... Main 4-3598
LINDSAY, OKLAHOMA
Rainbo Service Co. 530
MIDLAND, TEXAS
Lucoous Service & Eqpt. Co. ..... MU 2-1631
NEW ORLEANS, LOUISIANA
Assoc. Eng. & Eqpt., Inc. ..... VE 5-4933
OKLAHOMA CITY, OKLAHOMA
Rainbo Service Co. ..... ME 4-2131, ME 4-0105
WHITTIER, CALIFORNIA
Kline Wire Line Co. ..... OX 3-2731
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Hudson-Eads, Inc. 2-3767, 2-8584, 3-4690

for **leakproof, pressure-tight connections**

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Heat and vibration-proof, non-solvent, will not shrink, crack or crumble. Makes all assemblies leak-proof and pressure-tight. Prevents rust, corrosion, joint seizure.

7 BASIC BLENDS

LIQUID WRENCH®
The super-penetrating rust solvent

LOOSENS
rusted bolts, nuts, screws, 'frozen' parts

Liquid Wrench works *fast*... yet is absolutely safe for all metals and alloys.

2171

At Industrial, Automotive, Hardware, Plumbing Jobbers

SOLDER SEAL

RADIATOR SPECIALTY CO.
Charlotte, North Carolina

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president, was named vice chairman of the board. At the same meeting, the directors created an executive committee composed of Ambrose, chairman, Mosser, Bintliff, **J. G. Taylor** and **A. W. George.** Ambrose, before joining Associated in 1954, was vice president and manager of Southwest Gas Producing Company and Carbons Consolidated, Inc., and president of Monla Gas Co., Inc., all of Monroe, La. He was also a director of those companies and the parent company, Commonwealth Gas Corporation of New York City.

•

Bruce Jones will direct the Texas oil industry's public information and service program in 19 eastern counties during 1958 as East Texas Oil Information committee area chairman. The OIC program is sponsored by the American Petroleum Institute. Jones is products coordinator for the La Gloria Oil & Gas Co.

•

J. Paul Roston, former head of the Petroleum section in the Mining Engineering department at the Missouri School of Mines, has joined **Alex W. McCoy Associates, Inc.,** Tulsa, as staff engineer. Since 1947 Roston has been a consulting engineer and geologist on oil, and mineral properties, principally in Texas, the Gulf Coast, Oklahoma and New Mexico. From 1952 to 1954 he was assistant professor of petroleum engineering at The University of Texas, and from 1953 to 1956 he served as secertary-treasurer of the Southwestern Oil and Mineral Corp. He left to go to Missouri School of Mines in 1954. He worked for several years in south Texas oil fields before transferring to Tulsa in 1945 as a reservoir engineer. In 1949 he was promoted to head secondary recovery engineer.

•

Bandini Petroleum Company announced the election of **William L. Boyer** as president and a director, replacing **John P. Hurndall,** who has resigned. Hurndall will continue as a consultant to Bandini and will devote most of his time to the operation of the company's foreign oil concessions in British Honduras and Guatemala. Boyer has been executive vice president of Bandini and formerly was general manager of the Richard S. Rheem oil interests.

William A. Boyer

•

Kerr-McGee Oil Industries, Inc., has announced a number of changes in the drilling and Production departments. **G. Otis Danielson,** formerly regional drilling manager at Morgan City, La., has been transferred to Oklahoma City and assumes the duties of manager of the Drilling department. **Ken W. Parker** has become special assistant to Danielson and will handle foreign operations. **B. D. McCampbell,** contract drilling engineer, transferred from New Orleans to Oklahoma City, will maintain contacts with operators doing exploratory and development drilling in foreign areas and eventually will assume the coordination of similar activities in the Mid-Continent area. McCampbell's contract and proposal work will be carried out under the direction of the manager of the Drilling department. **Grier Zimmerman** has replaced Danielson as manager of drilling operations in the Gulf Coast region and **John Cox** has become supervisor of engineering and maintenance for the Gulf Coast.

•

G. Allan Nelson, geologist with Colorado Oil and Gas Corporation in Denver, has resigned to become a consulting petroleum geologist in Denver.

•

D. L. Kastner was appointed assistant general superintendent in **Cities Service Oil Co.**'s Production division. Increased activities made necessary the creation of another assistant general superintendency under **C. R. Smith,** general superintendent. **E. L. Cralle,** superintendent of the company's north Odessa, Texas, production operations has been promoted to assistant division superintendent at Odessa, to succeed Kastner.

•

Wade W. Turnbull, formerly assistant exploration manager for **The Carter Oil Company,** has been named manager of

BRITISH H/E MADE

300 P.A. TRACTOR DRILLMASTER

MULTI-PURPOSE · HIGHLY MOBILE

The Hands-England 300 P. A. Drillmaster Rotary Drill is now available mounted on a Fordson Major Industrial Tractor and is illustrated on left.

This design provides great manoeuvreability and is intended primarily to enable the well known H/E Drillmaster 300 P. A. Rotary Drill to be used for Quarry and Open Cast blast hole, shot hole, auger, core or sample drilling.

Although the H/E Drillmaster 300 P. A. mounted on a diesel engined agricultural tractor, is ideal for Quarry and Open/Cast operations, it is equally applicable to some difficult "off the road" locations, such as may be encountered during seismic exploration or shot hole drilling.

In areas where a light drill with high tractive effort and good manoeuvreability is required, the H/E Tractor Drillmaster will be found to have much advantage over the conventional type of truck mounted drill.

Standard equipment provides for drilling holes of 2⅜" to 4" in diameter or to ream out 2⅜" diameter holes to larger sizes. Extra equipment can be supplied for cutting larger holes up to 5⅝" diameter, if desired.

For flushing cuttings to the surface an air compressor can be mounted directly onto the H/E Tractor Drillmaster and driven by the Tractor Engine. The compressor can achieve an up-hole annular velocity of 3,000 ft. per min.—using 'B' rod and 3" dia. bits. If air drilling is to be employed for larger holes, or where mud circulation is necessary, the equipment for these operations must be mounted on a separate trailer or tractor.

The H/E Tractor Drillmaster will be found to cover the majority of drilling requirements of the Quarry and Open Cast operator, the Geologist, the Mineralogist, and the Geophysicist.

Write for illustrated folders giving full details and specifications of this equipment.

HANDS-ENGLAND OILFIELD EQUIPMENT LTD

MANUFACTURERS OF GEOPHYSICAL SUPPLIES

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the company's Exploration department. Turnbull will replace **M. W. Haas** who has also held the position of exploration manager, and who will henceforth devote full time to his position of vice president and contact director for exploration.

•

Monterey Oil Company announced the creation of a new vice presidency with the appointment of **Albert W. (Bob) Gentry** as vice president for operations. He has been promoted from manager of field operations. Gentry joined Shell of California in 1925, serving as torsion balance observer and resident geologist on several wildcat wells. He joined Fullerton Oil Company in 1952 as manager of field operations, continuing in the same capacity when the company was sold to Monterey.

Albert W. Gentry

•

Joseph Nalle was elected vice president and petroleum engineer of the Texas National Bank of Houston.

•

Charles W. Lane, geologist, has resigned from Falcon-Seaboard Drilling Co., and opened offices in the Mayo building, Tulsa, as a consultant. He formerly was associated with Indian Territory Illuminating Oil Co., The Pure Oil Co. and Deep Rock Oil Corporation.

•

Tennessee Gas Transmission Company and one of its subsidiary companies have made the following personnel appointments involving oil and gas exploration and production activities. **R. S. Randerson, Jr.,** has been named Production department coordinator for Tennessee Gas at its Houston headquarters. He was formerly assigned to the company's Gulf Coast division office in Bellaire, Texas, as assistant production manager. Named as petroleum engineer for the company's wholly-owned subsidiary, Chaco Petroleum, S. A., was **Morris E. Kittleson,** formerly production engineer for Merrill Petroleums, Ltd., Calgary, Canada. Kittleson has been assigned to the Chaco office in Cochabamba, Bolivia. **J. H. Hudgeons,** formerly district production clerk at Hobbs, N. M., for Tennessee Gas, has been assigned to Cochabamba as office manager for Chaco. Appointed office manager for the Tennessee Gas Overseas department in Houston was **H. G. Irwin, Jr.,** formerly division office manager for the company's Gulf Coast Production division at Bellaire.

•

Geophysical Service Inc., has made two supervisory appointments. **Ernest J. Malovich** assumed supervisory duties over GSI seismic field parties operating in India. He will maintain headquarters in Calcutta, India. Malovich joined GSI in 1950 as a computer trainee, and was serving as a seismic party chief in Pennsylvania at the time of his promotion. He will be succeeded in Pennsylvania by **Al Harris** who joined GSI in 1941 and has been serving as a party chief in Mexico since 1952. **John Utesch,** formerly a party chief for GSI in Mississippi and Louisiana, assumed supervisory duties over several GSI parties operating in the Southeastern area of the U. S.

•

William C. Elliott, Jr., formerly assistant chief of the Dallas office of the **Bureau of Mines,** has been transferred to Wichita Falls, Texas, where he will be chief of that office. The Bureau's office in Wichita Falls is concerned primarily with secondary recovery and other problems common to the North Texas area.

Hal F. Nabors has been promoted to general manager of **Continental Oil Company's** Central region in Oklahoma City. He was promoted to assistant Central region general manager in Oklahoma City in 1955 and has been serving as acting regional manager since March, 1957. Nabors joined Conoco in 1935 in New Mexico, where he served for two years as a tool dresser, water pumper and roustabout.

•

Kenneth Cervenka was appointed to the Midland, Texas, engineering staff of **Tekoil Corporation.** Cervenka, who will head the company's regional operations office in Midland, was associated with Shell Oil Company for five years prior to joining Tekoil.

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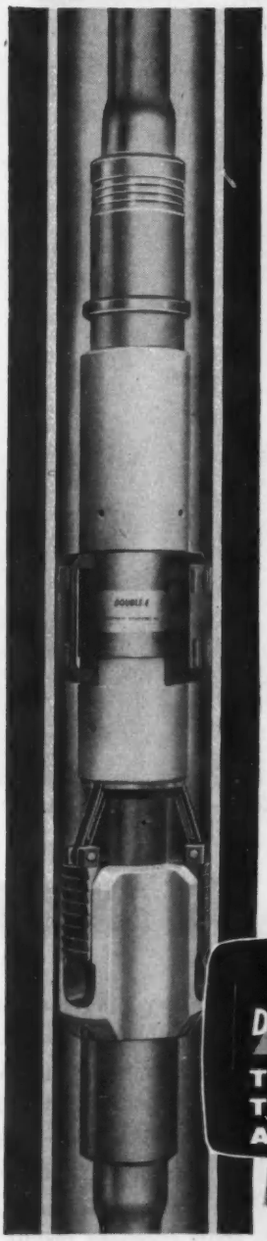

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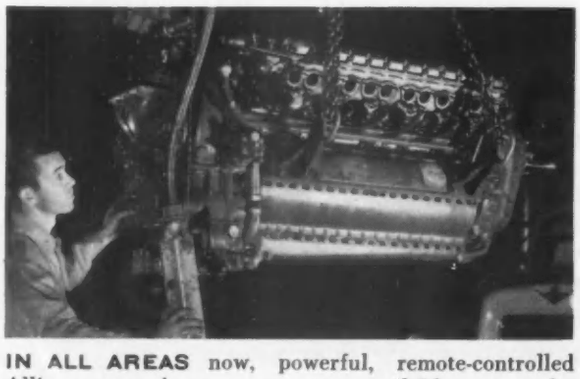
DOWELL RECENTLY PERFORMED THIS RECORD-BREAKING HIGH-INJECTION-RATE TREATMENT AVERAGIN[illegible] BE



IN ALL AREAS now, powerful, remote-controlled Allison-powered pumpers are available to make high-injection-rate fracturing economical. This mighty aircraft engine, heart of the pumping unit, has a maximum rating of 1500 horsepower and delivers 600 hydraulic horsepower from Dowell's high volume pumps.

HIGH-INJECTION-RATE FRACTURING BY DOW

Many operators are going to high-injection-rate fracturing for one simple reason. It gives them more oil for their money!

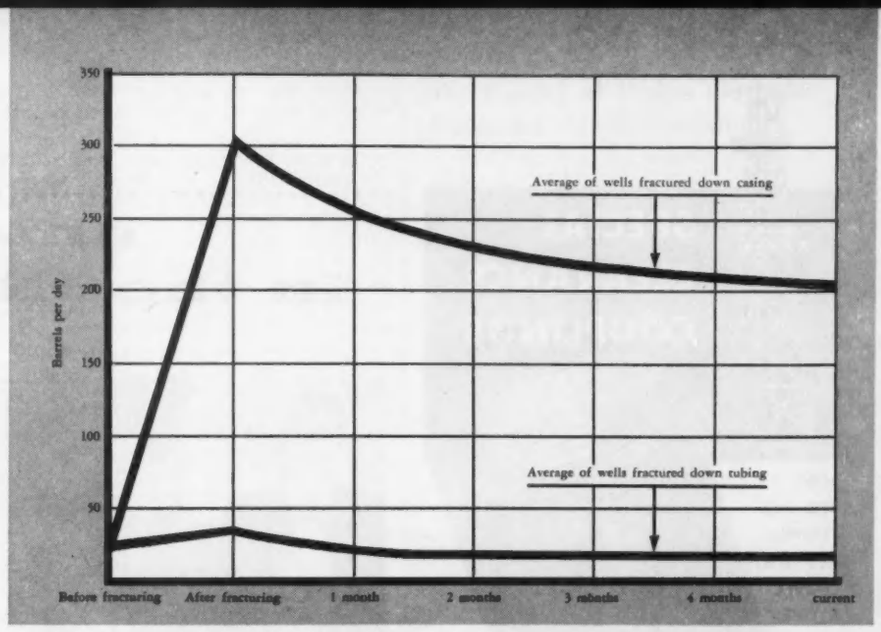
At first this may seem strange. More equipment is required for the treatment. The tubing string may have to be pulled.

When all factors are taken into consideration, the cost per job is considerably higher—but the results are often startlingly better.

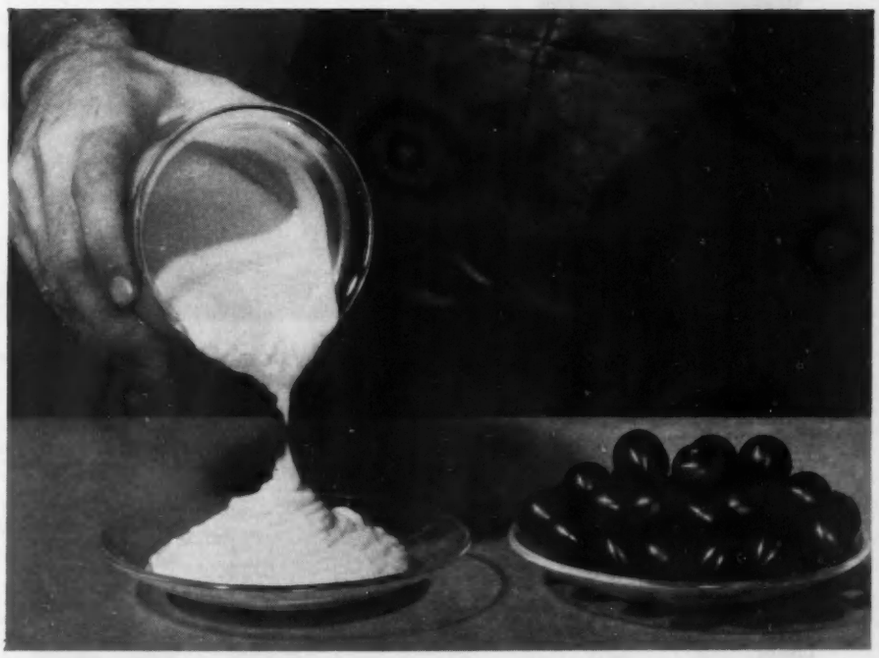
Many wells that do not respond well to fracturing down tubing show excellent results when tubing is pulled and injection rates are increased. The graph on the next page is an example of this fact as proved in one producing field.

To help make high-injection-rate fracturing practical, Dowell

RAGIN 1 BBLS./MIN. WITH 6250 HHP.



IN YOAKUM COUNTY, WEST TEXAS, a study was made by oil company engineers, comparing the results of high-injection-rate fracturing down casing with low-injection-rate fracturing down tubing. This study showed that casing jobs yielded far better results. The average initial increase was over 12 times as great. More important, however, production held up far better as shown on the graph.



NEAR SHREVEPORT, LOUISIANA, as well as other areas, some operators use Fixafrac® or ball sealers to improve the effects of high-injection-rate fracturing. Temporary plugging materials help spread the force of the treatment over the entire face of the pay for better results.

BYDOWELL—FOR GOOD ULTIMATE RECOVERY

developed the remote-controlled pumper powered by an Allison aircraft engine. This is still the most powerful unit—pound for pound—in general use.

Take advantage of the experience Dowell has accumulated in this service. For full information on the advantages of high-injection-rate fracturing, call any of the 165 Dowell service points in the United States and Canada; in Venezuela, contact United Oilwell Service. Dowell Incorporated, Tulsa 1, Oklahoma.

Services for the oil industry DOWELL

A SERVICE SUBSIDIARY OF THE DOW CHEMICAL COMPANY

PULLING TUBING can be one of the greatest aids to high-injection-rate fracturing. Many operators have found that the cost of pulling tubing amounts to only a small per cent of the total cost of fracturing. Yet, the production increase sometimes is more than twice as great.

use **EXTRA STRENGTH** for dual completion oil wells

These couplings have thinner walls and a special O.D. chamfer to accommodate two lines in one casing. Due to the thinner wall we recommend:

N-80 COUPLING FOR USE WITH J-55 TUBING
Identified by all-over red for N-80 and green stripe for use with J-55 tubing.

P-105 COUPLING FOR USE WITH N-80 TUBING
Identified by all-over white for P-105 and red stripe for use with N-80 tubing.

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What's Happening

among MEN in the INDUSTRY

Past and Present Geological Officers

The old and new officers are shown at the fifth 1957 Executive committee of the Gulf Coast Association of Geological societies in Houston. Seated left to right: H. N. Hickey, 1957 president; E. A. Lohse, 1958 president; E. T. Musselman, 1958 secretary; and R. W. Grayson, 1958 vice president. Standing left to right are R. B. Thompson, 1957 representative from Lafayette, La.; R. A. Davis, 1957 secretary; E. Monsour, 1957 representative from Mississippi; B. W. Fox, 1958 representative from East Texas; and E. A. Gibson, 1958 representative from New Orleans.

Geophysical Officers Take Action

These newly elected officers of the Permian Basin Geophysical Society recently took over their respective duties. From left: S. L. Hake, National Geophysical Company, secretary; R. A. Baile, Empire Geophysical Company, first vice president; B. B. Owings, Forest Oil Corporation, president; John M. Armstrong, Cities Service Oil Company, treasurer; and John E. Clark, Union Oil Company of California, second vice president.

NOMAD Officers for 1958

New York NOMADS elected these officers at their January meeting. Seated left to right are Herb E. Maland, senior regent, R. J. Eiche & Associates, Inc.; E. E. Andreason, president, Andreason-Lunberg Corp.; Don E. Kircher, vice president, Gardner-Denver Co.; and Maurice F. Delano, Jr., junior regent, R. S. Stokvis & Sons, Inc. Standing left to right are E. W. Hoeppner, executive secretary, Hughes Tool Co.; John E. George, assistant secretary, Mid-Continent Supply Co.; Harold E. Lowrey, Sergeant-at-arms, Continental-Emsco Co.; and W. E. Bolkman, treasurer, Cardwell Mfg. Co. Absent when the picture was taken was R. L. LeBus, Jr., assistant treasurer, Baash-Ross Tool Co.; Hollis W. Haltom, secretary, Haltom & Hickman; D. T. O'Connor, assistant sergeant-at-arms, D. T. O'Connor; and J. W. Chands, assistant sergeant-at-arms, A. O. Smith Co.

Kansas Oil Men's Group Elect Two, Re-elect Five

Members of the Kansas Oil Men's Association meeting for their 43rd annual convention elected two new directors and re-elected five directors to serve for the next three years.

The two new directors are Paul Maxwell, Southwest Gas & Equipment Co., and Hap Gunther, Schiereck Service. They replace retiring directors, A. D. Eubank, City Oil & Gas Co., and S. R. Knight, Princeton Oil Co.

Re-elected were C. C. Abercrombie, Home Oil Co.; Otha Hatfield, Hatfield-Jackson Oil Co.; Lyle Killion, Killion's Service Stations; Dean Kimmel, Kimmel Oil Co.; and R. H. McClellan, McClellan Oil Co.

Bowlby Is Again President of Western Oil, Gas Group

Samuel F. Bowlby, vice president, Shell Oil Company, and the company's representative on the West Coast, was re-elected president of Western Oil and Gas Association.

Other officers elected are Olen Lane, Continental Oil Company, first vice president; D. T. Staples, Tidewater Oil Company, second vice president; T. H. Wallace, Western Gulf Oil Company treasurer. Felix Chappellet was re-elected secretary, vice president and general manager.

Members of the executive committee are: Bowlby, chairman ex officio; B. E. Devere, Pathfinder Petroleum Company; Lane; E. J. McClanahan, Standard Oil Company of California, Western Operations, Inc.; Ross McCollum, National Oil Company; R. L. Minckler, General Petroleum Corporation; R. R. Von Hagen, Lloyd Corporation, Ltd.; and James T. Wood, Jr., The Texas Company.

Elected to the board of directors were: Robert O. Anderson, Wilshire Oil Company of California; L. L. Aubert, Bankline Oil Company; John S. Bell, Humble Oil & Refining Company; F. W. Borden, Sunray Mid-Continent Oil Company, Bowlby; Harold L. Briggs, Chanslor-Western Oil and Development Company; H. D. Campbell, Franco Western Oil Company; Devere; J. M. Feldman, Golden Bear Oil Company; E. B. Hall, Drilling and Production Company; John W. Hancock, Hancock Oil Company; Chas. S. Jones, Richfield Oil Corporation; W. M. Keck, The Superior Oil Company; Fred M. Keller, Oceanic Oil Company; Lane; A. C. Mattei, Honolulu Oil Corporation; McClanahan; Downs McCloskey, Amerada Petroleum Corporation; McCollum; Minckler; S. B. Mosher, Signal Oil and Gas Company; Lee S. Orborne, Union Pacific Railroad Company; Howard C. Pyle, Monterey Oil Company; Herbert L. Reid, Kern County Land Company; A. C. Rubel, Union Oil Company of California; George Sowards, The Ohio Oil Company; Staples; Jasper W. Tully, Reserve Oil and Gas Company; Von Hagen; Wallace; Wood; and John A. Woodward.

Dallas SPE of AIME Picks F. L. Oliver as Chairman

Fred L. Oliver, a Dallas consulting geologist, has been elected chairman of the Dallas section of the Society of Petroleum Engineers of the AIME for 1958.

Before becoming a consultant, he was associated with the Dallas firm of DeGolyer and MacNaughton as a reservoir and geological engineer. Prior to DeGolyer and MacNaughton, he held positions with Robertson Drilling Co. and Stanolind Oil and Gas Co.

Other new officers of the section for this year include O. K. McElheny, Atlantic Refining Co., chairman of the arrangements committee; Allen Gibson, Magnolia Refining Co., awards committee chairman; J. J. Arps, British-American Oil Co., long-range planning; Margaret Keiles, Atlantic, membership; C. H. Coldwell, Sun Oil Co., nominating; J. H. Kastrop, The Petroleum Engineer, publications; Tom Calhoun, DeGolyer and MacNaughton, program; J. H. Sullivan, Atlantic, study group; K. W. Robbins, Otis Engineering Corp., directory; Dan Goodrich, Dan Goodrich, Advertising, publicity, and Tom Kennerly, Core Lab., scholar.

Dr. Kinzel of Union Carbide Becomes AIME President

Dr. Augustus B. Kinzel, metallurgical scientist, presided over the February meeting of the American Institute of Mining, Metallurgical and Petroleum Engineers as its president.

Dr. Kinzel, who is vice president of Union Carbide Corp., will succeed Grover J. Holt, assistant to the president of The Cleveland Cliffs Iron Co. Holt will become past president. During the past year, Dr. Kinzel has held the offices of president-elect and director in AIME. He also has been a vice president of AIME and formerly was chairman of its Finance committee. He was Howe Memorial Lecturer in 1952.

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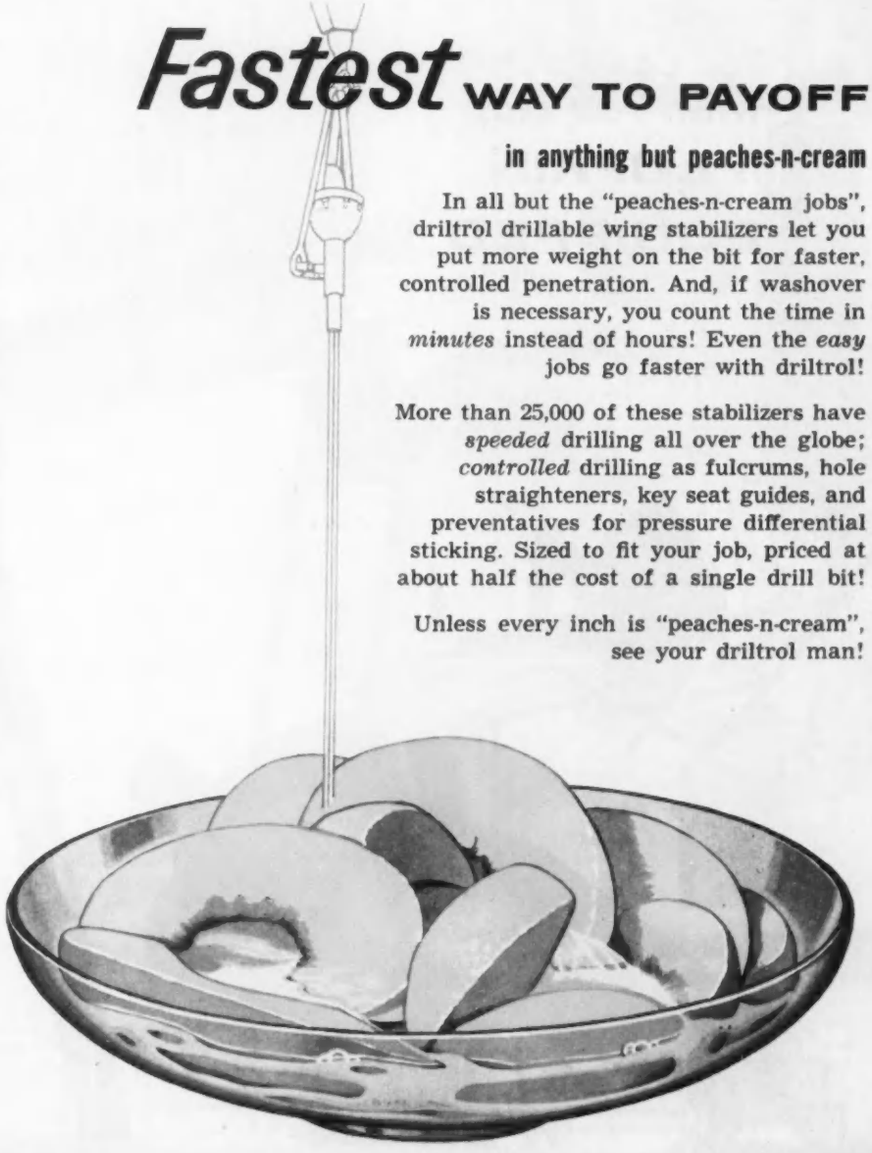

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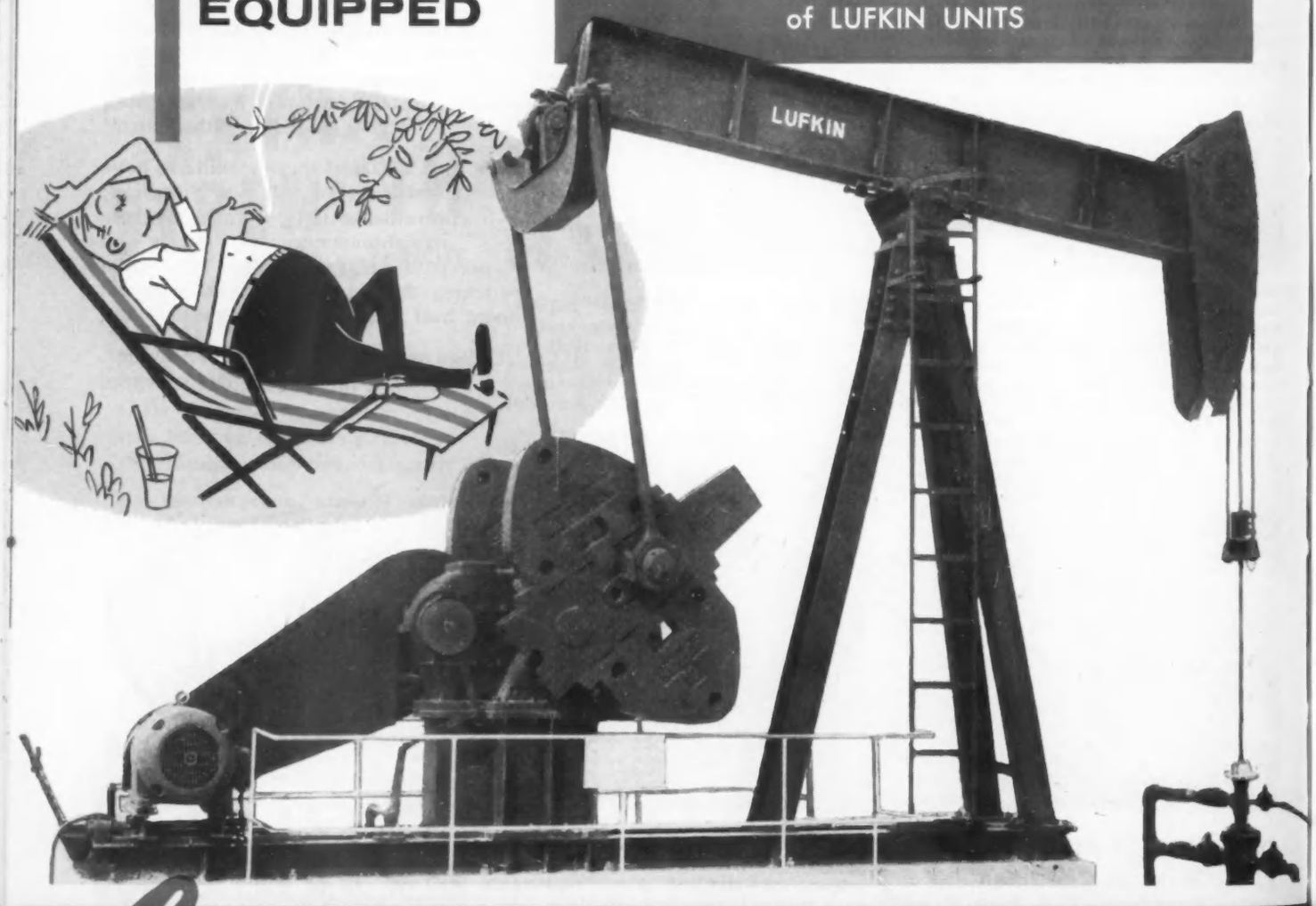

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COMPANIES in the News

CREOLE PETROLEUM CORPORATION has ordered a series of special-type barges for use in the Lake Maracaibo area of Venezuela from Avondale Marine Ways, Inc. Three of these barges are of the deck cargo type, 110 feet by 40 feet by 8 feet, designed primarily for the transportation of materials to various locations on, and adjacent to the Lake. Four other deck cargo barges, 110 feet by 50 feet by 10 feet, have been constructed for general well servicing in the Tia Juana district of Lake Maracaibo. Each of these barges will carry four hoppers, another four will be in transit between the barge and the bulk station, and four more will be at the bulk station in readiness for transporting to the job site.

•

AMERICAN PETROFINA, INCORPORATED, reached an agreement to acquire all of the major oil and gas holdings of **ATLAS CORPORATION.** Involved in the transaction are all of the assets of the wholly-owned Atlas oil subsidiary, **PETRO-ATLAS CORPORATION,** and its subsidiary **El DORADO REFINING COMPANY.** These include about 11 million of oil reserves, approximately 125 billion cubic feet of gas, the 20,000 barrel a day El Dorado oil refinery and some 500 petroleum marketing outlets. Under the terms of the agreement the consideration to be received by Atlas will be partly in cash, partly in common stock of American Petrofina and partly in new American Petrofiina convertible debentures. The total price involved was not disclosed. **Dale R. Snow,** who has been head of Petro-Atlas Corporation, is remaining with Atlas, which will continue in the producing end of the oil and gas business. It is expected that the transaction will be completed early in March.

•

TRANS-GULF OFFSHORE DRILLING COMPANY's new offshore drilling platform Number 10 was commissioned recently in the Houston Ship Channel. Built for operation off the coasts of Texas and Louisiana, this elevating deck type platform is 185 feet long (exclusive of the heliport) and 87 feet wide, and is capable of operating in water up to approximately 80 feet in depth. The hull for the rig was constructed by Port Houston Iron Works, Inc., and the elevating mechanisms were manufactured by Joe Stine, Inc. One innovation is the use of a mercury switch level control device. All the equipment including the elevating mechanisms were installed by Trans-Gulf crews. The compact design was achieved by installing most of the major equipment, other than the drawworks, mast and substructure, within the hull. One of the weight-reduction features is the use of IDECO, Inc., 1,250 horsepower mud-master slush pumps, which have a high ratio of hp per pound because of their all-steel construction.

•

DIXILYN DRILLING CORPORATION's first mobile offshore platform,

Dixilyn's "Julie Ann" is shown undergoing last-minute preparations for its christening ceremonies at New Orleans. The unit had previously been towed down the Mississippi River from Vicksburg, Miss.

the "Julie Ann," was christened recently in New Orleans. A number of new features are included in the platform, which was designed and built by R. G. LeTourneau, Inc. For instance, legs of the unit are 175 feet in length. Also a high-speed freight elevator runs the length of one leg—from a helicopter landing area to the deck at any elevation. Another feature is that the platform can raise or lower itself at a rate of one foot per minute, with simple electric switches operating all legs simultaneously, or for leveling purposes, each leg independently.

•

TENNESSEE GAS TRANSMISSION COMPANY has created a new Mid-Continent division Oil and Gas Production headquarters in Oklahoma City. The Mid-Continent division headquarters will be responsible for the company's production and drilling activities in Oklahoma, Kansas and north Texas, with administration over district offices at Oklahoma City, Great Bend, Kansas, and Wichita Falls, Texas. **J. P. Schmalz** has been named to head the new office as division production manager. He formerly occupied a similar position at the company's Central division headquarters at Midland, Texas. Other personnel assigned to the Oklahoma City division office include **H. E. Rowe, Jr.,** division petroleum engineer; **William Miskimins, Jr.,** production foreman, and **W. F. Lewis,** division production office manager. A number of other personnel reassignments were announced. These include **J. P. Jacks,** as division production manager at Midland, replacing Schmalz; **L. B. Plumb,** as division petroleum engineer at Midland; **L. C. Bodemann, Jr.,** division petroleum engineer at Denver; **J. L. King,** division production office manager at Denver; **L. P. Miller,** district petroleum engineer at Oklahoma City, and **E. L. Patterson,** district clerk at Wichita Falls.

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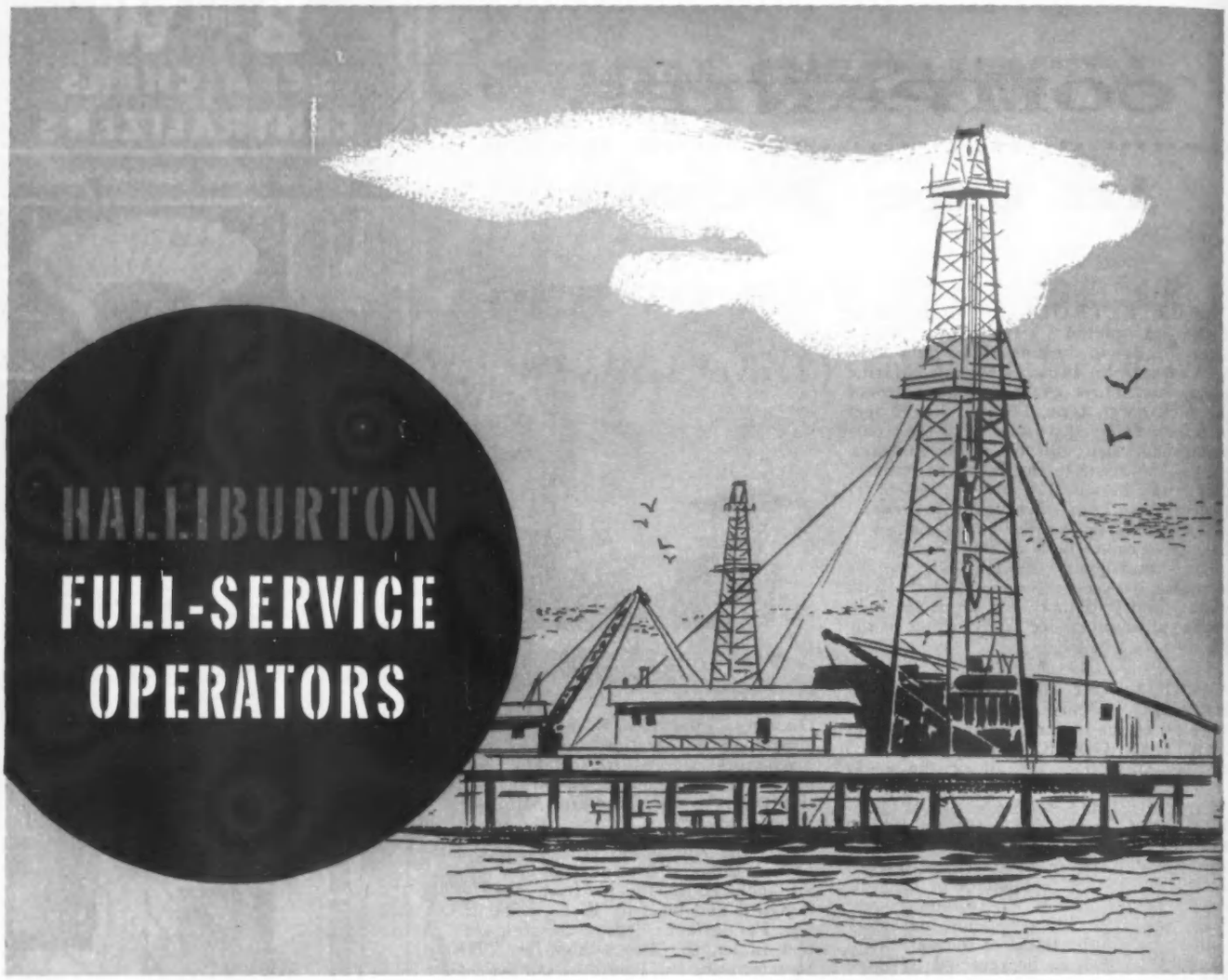

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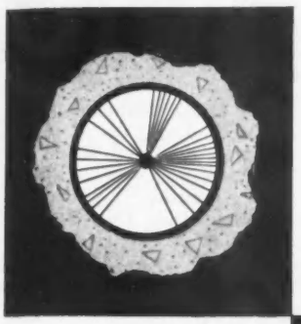
Halliburton's versatile POZMIX cements yield greater Offshore savings

Halliburton's standard Pozmix blend, *stored aboard the offshore drilling rig,* is sufficient for cementing operations from the mud line to 14,000 feet. Versatile Pozmix Cement is easily accelerated with additives for conductor jobs and shallow plug backs. Costs of moving fresh water are virtually eliminated since sea water can be used with Pozmix for surface and intermediate string jobs.

Halliburton's Pozmix 140 is also used in offshore operations. This blend with hydrated lime is formulated for use in wells from 6,000 to 20,000 feet and deeper... at temperatures from 140°F to 400°F and higher.

Join the many other satisfied offshore operators—put Pozmix to work for you full time.



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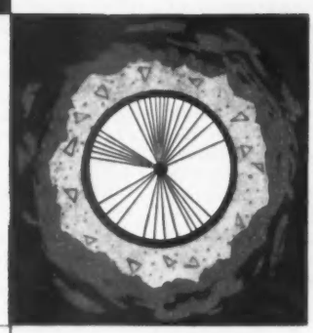

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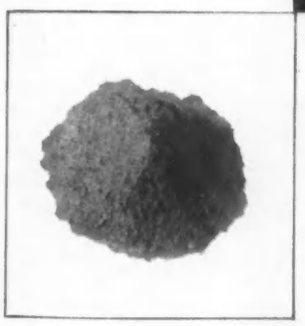
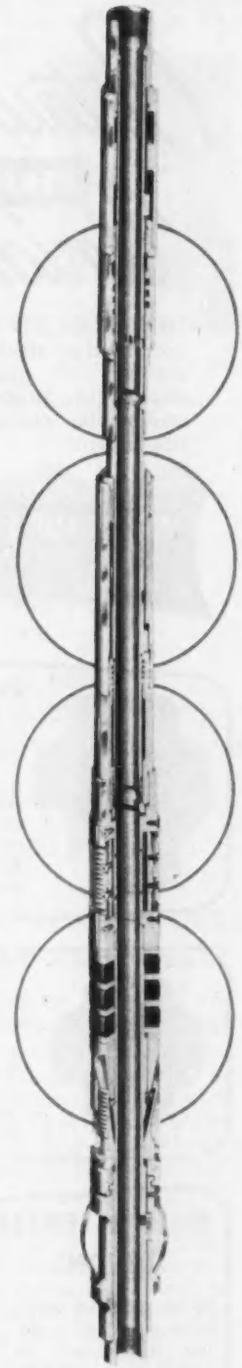


HR-4



RTTS PACKER

HR-4 WORKS WELL WITH POZMIX CEMENTS

Halliburton's HR-4 retarder converts standard Pozmix to an excellent blend for cementing, squeezing and plug backs at moderate depths and Pozmix 140 for deeper depths and higher temperatures.

RTTS PACKER (Retrievable-Test-Treat-Squeeze)

Here's one dependable combination tool that Halliburton offshore specialists rely on for one or more jobs on a single trip... acidizing, fracturing, testing or squeeze cementing. Simple tubing manipulation operates the RTTS Packer which has full opening mandrel for treatment with large fluid volumes or passage of tubing type perforating gun. Safety joint with drillability features for squeeze cementing. Circulating valve to equalize tubing and annulus pressures at Packer when desired.

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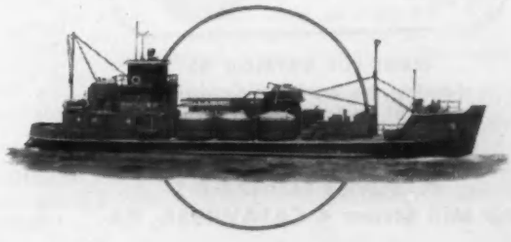
A new complete 52-page guide to Halliburton Pozmix Cements... containing a wealth of useful information and data... is yours for the asking.



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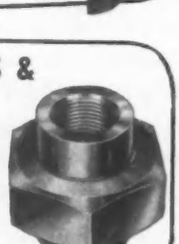

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H. C. Smith

Herschel C. Smith

Herschel C. Smith was elected president of the **H. C. Smith Oil Tool Co.** He was formerly executive vice president. **H. C. Smith,** founder and previous president of the company, was named to the newly created position of chairman of the board of directors. Herschel C. Smith, who has been associated with the company since 1936, was made general superintendent in charge of production in 1943 and became secretary and general manager in 1945. He was elected vice president and general manager in 1953 and, two years later, became executive vice president.

•

Horace J. Shumate has been named manager of the newly-opened foreign contracting office of **Loffland Brothers Company** at 45 Rockefeller Plaza, New York City.

•

Vertol Aircraft Corporation has elected **Dr. Felix A. Kalinski** vice president to coordinate and direct the activities of the Contracts, Customer Relations and Engineering divisions. He will continue to direct long-range planning for the helicopter manufacturing company. Dr. Kalinski joined Vertol last July as assistant to the president in charge of long-range planning. He had been vice president and general manager of Pereira and Luckman, an architectural and engineering firm at Los Angeles.

•

William C. Ridge has been elected vice president—production of **John A. Roebling's Sons Corporation.** Ridge has had 15 years' experience with Roebling. Prior to his appointment, he was works manager of the corporation and before that manufacturing manager of the Electrical Wire division. Earlier he was manager of the Standards Engineering division. He joined the Roebling Corporation in 1942 as an engineer.

•

William Earl Shorts, who for 25 years represented **The Wheland Company** in the Oklahoma oil fields, has retired from active duty. Shorts had earned from his associates the title, "Dean of Oil Field Servicemen." **Lee O'Shields** now represents Wheland as serviceman in Oklahoma City.

•

E. A. Ernst, who joined Dowell Incorporated as a clerk at Wichita Falls, Texas, in 1945 is now district engineer. Ernst succeeds **J. A. Harmon** who is now district engineer at New Orleans. As district engineer, Ernst will supervise Dowell's engineering developments and activities in the Wichita Falls district which comprises about 50 counties in North, Central and West Texas.

•

Peter L. Winter has been named **Security Engineering Company's** Eastern Hemisphere assistant sales manager. Winter, who will be based in London, will be responsible for expanded distribution of Security rock bits and other drilling tools to oil-active areas throughout the Eastern Hemisphere. Since 1946, Winter has served in various divisions of the oil industry.

•

Richard E. White has been elected president of the **Mission Manufacturing Company.** Until White's election, **Walter B. Sharp** served as both president and chairman. White has been with the company since 1938. He started with the company as a junior engineer and advanced through the engineering and production ranks. He was elected executive vice president in 1955.

Richard E. White

•

Charles A. Doh has been named U. S. representative for the foreign subsidiaries of the Schlumberger organization. Formerly, he was manager of customer relations for **Schlumberger Well Surveying Corporation.** He became associated with Schlumberger in 1934 and worked in various locations in Rumania, Venezuela, Texas and Illinois. He served as Illinois division manager from 1945 to 1951, moving to New Orleans as manager of the Southwest area.

•

Charles D. Krieg of the **Tretolite Company** division of **Petrolite Corporation,** has

been assigned to Houston to carry on liaison work of field to the central research and development program. He succeeds **Ed A. Baumstark,** who recently was appointed assistant to **L. A. Bainter, Jr.,** manager of the Southern division. In his new capacity Krieg will also devote much of his time to special services in refinery problems.

•

Lester G. Evans

K. S. Ramey

Lester G. Evans has been appointed general sales manager for the **Axelson Manufacturing Company,** division of U. S. Industries, Inc. **K. S. Ramey,** former sales manager, has been promoted to assistant to the president. Evans was formerly vice president and general manager of the All-Power Manufacturing Company. Prior to that time, he served as assistant to the president of Emsco Mfg. Co., with prime responsibility for manufacturing plants in Los Angeles, Houston and Garland, Texas. Other duties at Emsco included plant manager of the Garland plant; chief engineer of the D-B division; assistant California sales manager; and other field sales positions.

•

Drilco Oil Tools, Inc. of Midland, Texas, has announced that **Glen Chance** has been appointed representative for the Ark-La-Tex district. Chance was formerly with Baash Ross Tool Company, Republic Supply Company and served for three years as sales and service representative with Lee C. Moore Company.

Glen Chance

•

Frederick J. Borheck has been named aviation sales manager of the International division of **Bendix Aviation Corporation.** Borheck will direct the activities of the overseas distributor organization of the division from its New York headquarters. He will also be responsible for export sales of aviation, industrial and electronic products manufactured by the corporation. In addition, he will direct the activities of the division's technical and engineering staff stationed abroad. He joined the staff of the International division 18 years ago, and has served in various sales capacities. Previously he was assistant sales manager of the Aviation department.

•

Burleigh Bozant has been promoted to vice president and assistant general manager of **OTM Corporation.**

Mid-Continent Supply Company recently named a new district manager and two new store managers. The new district manager at Wichita, Kansas, is **W. B. Nance,** former city salesman at Midland, Texas. Assuming new duties as store manager at Mid-Continent's store at Drayton Valley, Alberta, is **J. L. Kenny. R. C. Walters** was named store manager of the company's Shreveport location. Other recent personnel changes include the promotion of **J. E. Goodwin** from district machinery salesman at Casper, Wyo., to division machinery saleman at Denver. Assuming new duties recently as field salesmen were **B. W. Griggs,** Odessa, Texas; **Jack Howarth,** Red Deer, Alberta; **H. G. Molloy,** Houma, La.; **B. J. Perrin,** Farmington, N. M.; and **B. G. Swaringen,** Brownfield, Texas.

Charles W. Turner has been appointed Southern division sales manager of **The S. M. Jones Company,** with factory in Toledo, Ohio, and General Sales office in Tulsa. Turner will be the immediate supervisor of those S. M. Jones Company district representatives located at Midland, Dallas, Wichita Falls, and Houston, Texas, and Shreveport, La. Turner was employed by S. M. Jones in 1936, as a field engineer and subsequently as district representative of the territories

Charles W. Turner

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For Perfect Interaction Between the Swivel and the Rollers of the Bushing!

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The superior design of VARCO ROLLER KELLY BUSHINGS provides perfect interaction for the Swivel and the Rollers of the Bushing. The Rollers, being located on one level, act not only as a driving mechanism, but also as a guide to the Kelly Stem, and in no way interfere with the constantly moving swivel due to unfavorable working conditions or location. The Swivel, being in reality a universal joint, is unencumbered in its motion. This eliminates friction and prevents bind on the Kelly. The Kelly stem follows the Drill Stem freely and as the bushing revolves smoothly, and noiselessly in the table the Kelly is not restricted.

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• One Varco Roller Bushing Body is adaptable to all types and sizes of Kellys • Rollers mounted on Roller Bearings fully envelop the Kelly • VARCO Roller Kelly Bushings, with exposed Rollers, can be completely washed of mud • VARCO Roller Kelly Bushings always remain in the table when reaming, drilling up, or jarring.

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For more data on advertised products, use Readers' Service Cards, last page.

of Shreveport, La., Wichita Falls and Midland, Texas. He will headquarter in Tulsa.

Brown Well Service to Make H_2Oil Engineering Equipment

Brown Well Service of West Texas has taken over the manufacture of all H_2Oil Engineering Co. equipment. Under the agreement, H_2Oil products, including emulsion treaters and well testers, will continue to be manufactured at Tulsa under the same trademark, by the H_2Oil Equipment Division of Brown Well Service.

H. C. Brown of Odessa, Texas, will continue as president of Brown Well Service, and Russell D. May will become general manager of the H_2Oil Equipment Division. A. J. Hale will become general sales manager. The company will also maintain its district sales and service offices in the Southwest.

Midland Attracts Drilco Sales Representatives

From Wyoming to the Louisiana Gulf Coast, Drilco had sales representatives for the regional sales conference in Midland, Texas. Representatives attending the meeting are shown above, left to right (seated), Glen Chance, Ark-La-Tex representative, Shreveport, La.; Donald Morris, Houston, Gulf Coast division manager; Evelyn Aiken, sales secretary, Midland; Bill Bachman, sales manager, Midland; Stanley Moore, president, Midland; Bert Fairchild, Kansas-Texas Panhandle representative, Liberal, Kansas; Dick Norton, Oklahoma-North Texas representative, Oklahoma City; (standing) J. M. Wigley, Rocky Mountain representative, Casper, Wyo.; J. D. (Dobbin) Cloninger, Louisiana Gulf Coast representative, Lafayette, La.; Marvin Peck, Texas Gulf Coast representative, Houston; Moak Rollins, production and engineering manager, Midland; Bill Nelson, Four Corners representative, Farmington, N. M.; V. V. Hibler, operations manager, Midland; Bill McCutchen, general office manager, Midland; J. B. (Doc) Long, North Texas representative, Graham, Texas; Bill Garrett, research engineer, Midland; and V. V. McGrew, special sales, Midland.

You'll win more than this prize. You'll increase drilling efficiency and control your mud better. Mud-O-Graf records every variation in mud weight, saving time and costly errors in the addition of weighting materials. All heavy and light streaks in the circulating system and their duration are recorded. Mud-O-Graf shows how often the hole is filled up when coming out of the hole and shows the time of a complete circulation. If it's a question of mud, ask for Mud-O-Graf.

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Manufacturers of Pit-O-Graf and Rig Runner.

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Chemical Process Division Adopts BJ Service Name

Chemical Process Division is adopting the name and trademark identity of BJ Service, Inc., effective immediately. Chemical Process has been operating as a separate division of BJ Service since their merger a little more than a year ago.

Previously, Chemcial Process had specialized in oil well acidizing, fracturing and special chemical treatments throughout Texas, Oklahoma, Louisiana, Kansas and New Mexico. General offices of the firm are located in Fort Worth, Texas.

A new unified plan of organization and operation has also been adopted. The plan divides BJ Service into five operating divisions. They are

West Texas division, Midland, Texas. L. H. Kaltenberger is division manager.

Mid-Continent division, Fort Worth, Texas, with B. L. Crone as division manager.

Gulf Coast division, temporarily located at Fort Worth, Texas, while preparations are made for permanent office quarters in Houston. Division manager is C. R. Cross.

Pacific Coast division, Long Beach, Cal. J. T. Streger is division manager.

Rocky Mountain division, Denver. Division manager is C. Z. Hughes.

Executive sales officers named are G. R. Whitney and F. D. Smith. Operations will be managed by W. T. Box, with J. V. Derrick as assistant manager.

As another important part of the unification, the Engineering Development and Manufacturing division will be consolidated under the managership of M. B. Riordan in Long Beach. The company laboratories at Breckenridge, Texas, supervised by V. C. White, will concentrate on research in chemical services, including cementing, fracturing and acidizing. The Long Beach laboratories, supervised by R. F. Meiklejohn, will specialize in development work on electrical and mechanical equipment and wire-line services.

Manufacturing operations on the company's high-pressure pumping units and auxiliary equipment will be performed at the Long Beach plant, under the super-

Advancements?

Nothing Matches SHAFFER In Hydraulic Control Gate Features!

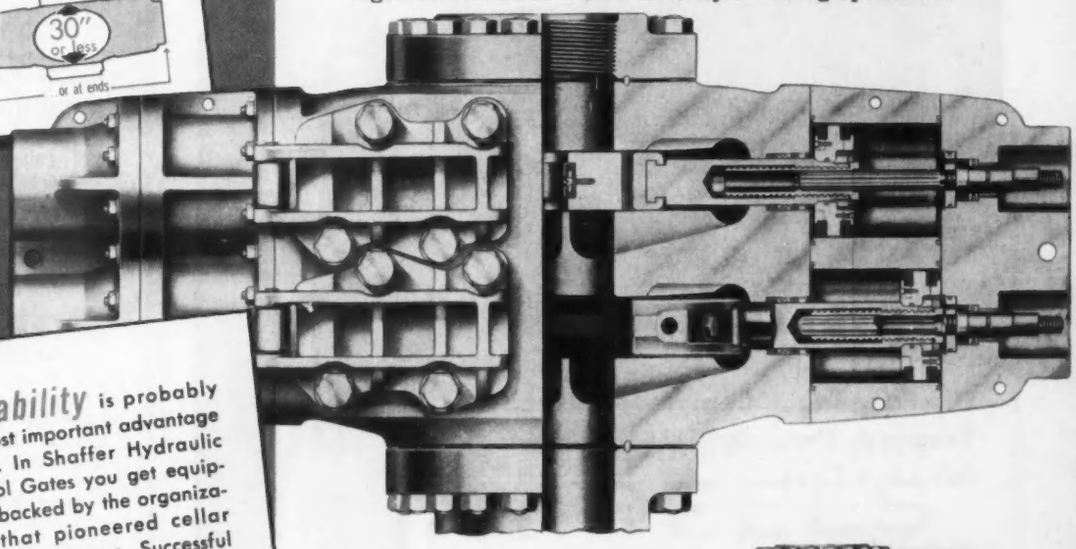
When you buy an automobile you look for more than transportation alone. And likewise when you buy hydraulic gates, you should look for more than just a means of controlling pressure. Look for the important advancements that save crew time on service operations... that save valuable space in the cellar ... that mean longer life, minimum maintenance, greater value per dollar.

No other equipment matches Shaffer on the vital *extra* advantages that mean so much on today's drilling operations!

SHAFFER Convenience in changing rams is unequalled in the industry. Simply unbolt and swing open two side doors, slide out the ram assembly, change rams, slide the assembly back in place and bolt the doors. Closing the doors automatically aligns the rams within the gate... and rams can be changed with equal ease whether pipe is in or out of hole.

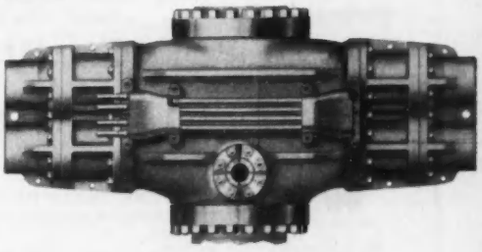
Compare these Shaffer advantages with other designs!

SHAFFER Compactness is permanent compactness, for there is no need to expand Shaffer gates in order to change rams. Even in sizes as large as 13⅜" (12" Series 900), Shaffer Hydraulic Single Gates require only 18½" total height... Double Gates (with two compartments in one compact body) require only 30." Width and length dimensions are also unusually compact, thus making a three-way saving in valuable cellar space!



CUTAWAY VIEW
showing direct hydraulic drive and self-draining ram compartments.

SHAFFER Dependability is probably the most important advantage of all. In Shaffer Hydraulic Control Gates you get equipment backed by the organization that pioneered cellar control gates over three decades ago. Successful from the first gate built, a program of constant development has kept them ahead of the industry and its pressure requirements. In every oil field of the world Shaffer Gates are recognized for their advanced design and rugged dependability!



REAR VIEW
showing simplicity of hydraulic manifolding for operating the gate.

SHAFFER Mud-Free Design prevents detrimental mud accumulations from interfering with free opening and closing of the rams. Note how each ram travels on high, narrow guide ribs above the steeply-sloped compartment bottoms so that mud and sand quickly drain back into the well. Also, this design permits well pressure to flow to the back of each ram, thus actually assisting the ram sealing action.

SHAFFER Direct Drive eliminates all complicated hook-ups (yokes, multiple pistons, etc.) between rams and hydraulic operating pistons. Each hydraulic cylinder is directly behind the ram it operates, with no off-center or other unnecessary connections. Furthermore, the single-piston-per-ram means simpler maintenance because there are fewer parts to service, quicker accessibility.

Get all the facts on Shaffer Hydraulic Control Gates before you invest in *any* pressure control equipment.

And if you use *mechanically*-operated control gates, Shaffer provides a complete line of this equipment, too, in both Single and Double Gate designs.

Write for your free copy of Shaffer's latest catalog!

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35 years OF OIL TOOL LEADERSHIP

vision of D. J. Kliment and at the Breckenridge facilities under the supervision of C. F. Hogan.

The exterior of Oil Center Tool Company's new warehouse near Lafayette, La.

Oil Center Tool's Warehouse To Service South Louisiana

Five thousand square feet of space for stocking complete lines of christmas trees and wellhead parts, in addition to assembly, testing and renovation services are incorporated in the new warehouse recently put into operation by the Oil Center Tool Company three miles east of Lafayette. The new facility will service south Louisiana.

In addition to the 50 by 100-foot warehouse, the structure includes a modern, brick office building.

Oil Center Tool's new facilities are the district headquarters for south Louisiana. District manager is D. L. Tanner. Sales representatives working out of the south Louisiana headquarters are Gil Lastrapes and Charles Linscomb. Warehouseman is Bob Chachere.

Mid-Continent Supply Picked As Delta Tank Mfg. Co. Agent

Mid-Continent Supply Company will be world-wide (except Mexico) exclusive distributor of the oil field equipment products of Delta Tank Manufacturing Company of Baton Rouge, La. The sales agreement covers sales and service to the export, domestic and Canadian markets.

Under the sales arrangement, Mid-Continent will distribute Delta's complete line of oil field equipment, including tanks, separators, heaters, treaters and process equipment.

Wyatt Metal & Boiler Renames Subsidiary Outside Mexico City

Wyatt de Mexico, S. A. de C. V. is the new name for Productos de Hierro y Acero, S. A., a subsidiary of Wyatt Metal & Boiler Works. The concern whose plant is at Tlalnepantla, Estado de Mexico, outside Mexico City, was purchased by the Texas concern earlier this year.

Officials of the concern are T. J. Uhl, Jr., president and general manager; Lic. Juan M. Steta, secretary and a director; Lic. Augustin Santamarina, director. Uhl was production manager of Wyatt's Dallas plant prior to his move to the subsidiary in Mexico.

ALCO Package Assembly Plant Completed in Beaumont, Texas

ALCO Products, Inc., has completed and put into operation at Beaumont, Texas, a complete diesel-electric power package assembly plant which will reduce time in shipments.

Previously, ALCO assembled its diesel-electric units for this part of the U. S. in Schenectady, N. Y.

ALCO technicians and engineers will assemble the power packages on a giant slab which provides 12,000 feet of working area. A feature of the new facility is a "Texas-size" fork-lift truck, the largest ever put into use in the Southwest, which has a lifting capacity of 20 tons. The truck will be used to position the engine-generator sets, motors and control cabinets which are basic components of the ALCO diesel-electric power package.

W. R. (Bill) Jones has been named product supervisor, diesel-electric power package, and Thomas A. Gallagher is now project engineer for drill rigs and oilfield equipment.

Gardner-Denver Co. Pump Line Increased by 85 Field Outlets

Gardner-Denver Company is broadening distribution of its line of pumps to the petroleum industry through addition of the 85 field outlets of Jones & Laughlin to the 92 outlets of Continental Emsco Co. that now distribute them.

Only California will be an exception to this broadened distribution program. In California the Republic Supply Co. of California will continue to be exclusive distributor of Gardner-Denver pumps and parts there, said Gutekunst.

Spartan Aircraft Company Ships Camp Facilities to Istanbul

Mobile camp facilities and equipment will play an important role in drilling operations soon to be launched about 100 miles west of Istanbul, Turkey, by Keir & Cawder Arrow Drilling (U. K.) Ltd.

The drilling contractor firm purchased 20 industrial units from Spartan Aircraft Company, Tulsa. Most of the Spartan equipment has been shipped and will arrive at the Turkish camp site well ahead of drilling equipment and crews. Included

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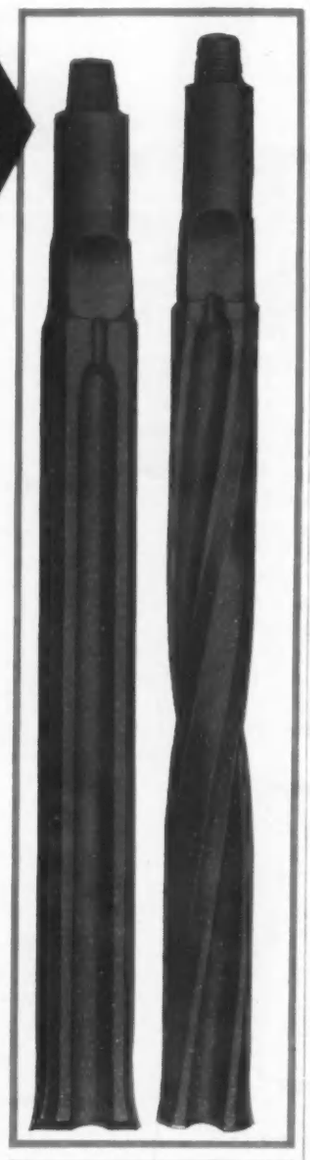
Die Forged . . . Completely Heat Treated They Drill More Hole for Less Cost

Made in Butler, Pa. . . . used 'round the world . . . SPANG BITS are BEST:

1. DIE-FORGED—gives uniform section from end to end.
2. FULLY HEAT-TREATED—they have maximum grain refinement assuring stronger pin, collars and blade sections.
3. TOUGH BLADE SECTIONS—means maximum penetration in hardest formations
4. PROPER DESIGNED WATER COURSES—providing better mixing, more room for cuttings and allowing faster drilling.
5. SEMI-DRESSED DRILLING ENDS—bits dress out to gage quicker with fewer heating.
6. SELECT YOUR STEEL—made in high carbon and two grades of alloy steel—select the one best suited for your conditions.



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For over 60 years manufacturers of Spang Weldless Jars and a complete line of Cable System Drilling and Fishing Tools for oil and gas wells, water wells, prospect drilling and shot blast holes.

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SEE COMPOSITE CATALOG for ENTIRE LINE!

in the package purchase are family housing units and four-man sleepers, recreation and laundry, radio and office unit, and units for kitchen and dining, refrigeration and storage and a field laboratory.

First drilling rig slated for this project is now being completely checked out in Houston. Its equipment will include a Lee C. Moore 142-foot mast and National 80-B drawworks.

The rigs to be used in Luzon are capable of drilling shallow gas and oil wells as well as large diameter irrigation wells, and they also can be used for foundation testing, quarry drilling and mineral exploration.

Failing Equipment to Be Used In Luzon Water Supply Project

American-made rotary drilling equipment will be used in the development of a large domestic water supply project on the island of Luzon in the Philippines. Under a contract between Shamrock Well Drilling Enterprises, Inc., and the Philippine government jointly with International Cooperation Administration (ICA) of the U. S. government, the project is scheduled to get under way in the immediate future.

Four Failing 1500 HD Holemaster rotary rigs will be used in the drilling program. The rigs were manufactured by the George E. Failing Company, a subsidiary of Westinghouse Air Brake Company. The rigs were shipped to Luzon from the port of Houston. The Failing Company also manufactured and supplied the special electric logging machine required for this project.

A group of 12 American drilling technicians accompanied the rigs to Luzon, and they will serve as instructors in the use of the equipment.

Under the terms of the contract more than 1000 wells are to be drilled on the island under the supervision of the American firm.

Marc Donnelly is president of Shamrock and Howard J. Weber is vice president in charge of operations. Donnelly has lived in the Philippines since 1946 and Weber also spent six years there in connection with well drilling and irrigation projects.

Ideco, Inc., Names Sales Agent For Graver Tank and Mfg. Co.

The appointment of Ideco, Inc., one of the Dresser Industries, as exclusive export sales representative for the Oil and Gas Equipment division of Graver Tank and Manufacturing Co., Inc. has been jointly announced. No change will be made in the distribution of Graver's oil field products within the U. S., which will be handled by the company's own sales and service facilities in more than 20 oil-producing centers throughout the Southwest and Rocky Mountain areas.

National Supply Renovates Its Oklahoma City Store

The National Supply Company has completely modernized its store at Oklahoma City, in use since 1929. The building was remodeled under the company's modernization program. The modernization program is intended to improve services and facilities of the company's store system and to give an over-all family resemblance to the company's oil field supply stores.

In addition to the construction of a new store front and canopy for the Oklahoma City store, the interior was completely remodeled and equipped with new storage shelves, sales counter, and furniture. Facilities of the pump shop were also improved.

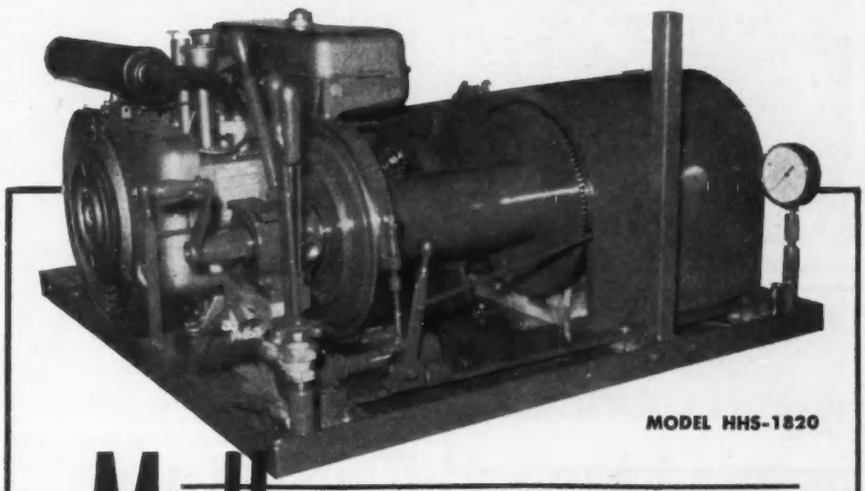
Wayne Showalter is store manager, under supervision of W. M. Jones, Oklahoma City district manager.

Poster and Company Formed To Offer Business Consulting

A company of business and corporation consultants has been formed in Tulsa, Russell E. Poster announced. Others in the firm are Harold B. Searles and Herbert B. Baber, Jr. All three have been associated with the oil industry or in allied industries.

Poster and Company was organized to utilize the varied talents of the three partners to offer businesses and corporations a comprehensive program of analysis, recommendation and assistance in the fields of finance, marketing, production, organization and accounting.

Poster has served as general sales manager, treasurer and vice president with companies in the metal trades manufacturing and oil field equipment sales fields. He also served as a staff consultant with a large eastern consulting firm. Searles has a 22-year background as vice president, treasurer, controller and director of large eastern manufacturing firms. Baber has spent eight years in the newspaper, public relations, advertising and sales promotion fields.



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Mathey Reels are available in many sizes with various drives and controls in combinations to completely meet every requirement. Choose your type of control — hydraulic or mechanical, your capacity, your line speed and pull, and your type of power—hydraulic air, electric or internal combustion engine.

Mathey's many years of experience guarantee you extra heavy duty construction, precision machining, oversize bearings and forged steel drum flanges. Mathey also engineers and manufactures specialty reels to fit your individual requirements.

USES:
- Bottom Hole Pressures
- Temperature Surveys
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SALES ENGINEER WATED

Well-established successful firm has opening in an expanding sales department for young man looking for an opportunity in sales work. Must be college graduate, not over 33, in good health and not afraid of work. Oil industry experience desirable. Applicant will be trained at home office before moving into sales work on basis of salary plus commission incentive and traveling expenses. Our own sales personnel know of this advertisement. Your reply will be confidential and should be sufficiently complete to merit contacting you for an interview. Address Box 153-W, WORLD OIL, Houston, Texas.

WANTED: Experienced accountant for aggressive, Denver based, independent oil firm. Must be able to assume office manager position. Excellent salary for top caliber man. Send complete resume to Box 146-W, WORLD OIL, Houston, Texas.

WANTED: Geologist with top qualifications for top paying job with aggressive Denver independent, active in Colorado and Canada. Canadian experience desirable but not necessary. Send references and qualifications to Box 145-W, WORLD OIL, Houston, Texas.

■ Sales Engineer by major tubular manufacturer for southwest. Field experience desired but not required. Salary dependent on background. Car and expenses and other substantial benefits. Box 150-W, WORLD OIL, Houston, Texas.

BUSINESS SERVICE

■ Delaware Corporations formed and serviced. Inquire without obligation. American Guaranty & Trust Company, 910 West Street, Wilmington, Delaware.

■ INCORPORATE in Nevada for oil and mining projects. Do business anywhere. Positively no liability of organizers and stockholders. Over 25 years experience. Financing assistance at no additional cost. Write for Resume. L. O. Goodman, L.L.B., Box 991 Globe, Arizona.

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SITUATIONS WANTED

■ Petroleum Engineer: 29, family, four years experience oil and gas production, gas processing and transmission. Obtaining MBA degree in June, available July. Desire Administrative position requiring Engineering knowledge with independent Producer. Box 151-W, WORLD OIL, Houston, Texas.

■ Available: American executive for overseas business. Age 35, married, LLB. 5½ years experience Europe, Africa, Middle East. Speak Arabic, familiar with French, Spanish, German. Experiences in foreign government negotiations. Detailed personal history data and references furnished on request. Box 152-W, WORLD OIL, Houston, Texas.

FOR SALE

■ Magnetometer, Vertical temperature compensated ten gammas scale division. Askania. Excellent condition. $900.00. Box 149-W, WORLD OIL, Houston, Texas.

■ 2 used latest model Wheland HP 14000 7-1/4 x 14 power slush pumps, excellent condition—one completely overhauled under factory supervision. Other good used drilling equipment. Industrial Supply Company, 500 8th Street, Wichita Falls, Texas.

FOR SALE: Model RL Cardwell spudder. Equipped to service 8000 foot wells. In excellent repair. Presently operating Ft. Morgan, Colorado area. Considerable company work will be given purchaser. Contact Lowell J. Williamson, 2150 South Bellaire, Denver, Colorado, SKyline 6-8333.

FOR SALE

5 x 10 KLS 1 Worthington Mud Pump, with MZ Waukesha Skid Mounted and one 5 x 10 FXO belt driven with Waukesha Engine.

One 7¼ x 12 Wilson Snyder Pump. 7 x 14 Bethlehem, two inch CMC centrifugal pump. 85 cubic Ingersoll Rand Compressor, gas driven.

750 foot drilling rig, complete trailer mounted.

Halliburton power driven measuring assembly. 12 inch OBL Brewster Rotary.

Let us store or sell your surplus equipment. Box 814, Houston 1, Texas. MIssion 5-3318.

WO Classified Ads Don't Cost...They Pay

BJ Service Inc. Launches Lake Charles, La., Operation

The opening of a new station in Lake Charles, La., is announced by BJ Service, Inc., a subsidiary of Borg-Warner Corporation.

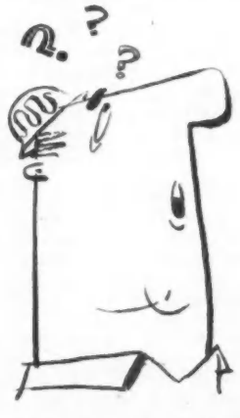
All of the station's equipment is of the latest BJ design. The pumping fleet is made up of 111-TB's, the rugged new trucks designed for high-pressure, high-volume operations. The bulk cement plant has four 3600 cubic feet silos, and a large warehouse contains large quantities of sacked materials to assure immediate supplies of the correct mix for any job in any required amount. The blender can handle up to 350 cubic feet of materials at once.

The new station is under the direction of Gulf Coast district superintendent, R. P. Kirkpatrick, who headquarters at the new district office at Lafayette. Station manager at Lake Charles is W. W. Ryan and sales engineer is Denis I. Mouton.

International Tool & Supply Co. Is Export Agent for Gulf Oiltool

Gulf Oiltool Company, announced the appointment of International Tool & Supply Co., Inc., as exclusive export agent for all countries other than Canada.

They also announced the appointment of the following exclusive agents for the Gulf Oiltool casing scraper: East Texas area, Texoma Oil Tool, Inc., Kilgore; West Texas area, Harrie's Sales & Rentals, Inc., Odessa; Four Corners area, Harrie's Sales & Rentals, Inc.



HAVE YOU FORGOTTEN SOMETHING?

The 1957 Editorial Index of all 14 issues of World Oil is now being mailed to subscribers requesting a copy. This convenient index covers all editorial matter published last year, by author and by subject.

To get your copy, merely drop a request to Librarian, Gulf Publishing Company, Postoffice Box 2608, Houston 1, Texas. Or if you prefer, use the blue Reader's Service Postcard in the back of this and every issue of World Oil.

If you have ordered but have not received your index, please be patient. We are trying to fill the requests as fast as we receive them. The supply is limited.

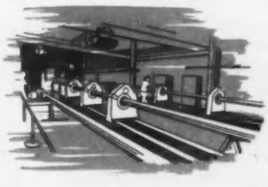
Why AMERICAN IRON Drill Collars Last Longer ... Increase Drill String Efficiency!

Exacting Metallurgical Control

Our metallurgists check and accept from the mill only those bars of uniform micro-structure which meet the high specifications for American Iron PREMIUM drill collar steel!

Advanced Manufacturing Techniques

Precision machining of outside drill collar diameter and micro-accurate "coring" produce a uniform end-to-end wall thickness. Precision threaded connections are microized to prevent sticking and galling.



Quality Product Reputation

With the finest record of drill collar performance in the field today ... both Domestic and Export ... American Iron is consistently first in the manufacture of premium steel drill collars.

PRECISION MACHINING of outside drill collar diameter and micro-accurate "coring" produce a *uniform wall thickness* end-to-end, minimizing the possibility of bending or kinking in the hole. This *balance* in American Iron drill collars is a safeguard against unnecessary drill string vibration! Over-all heat-treating of each bar assures a uniform micro-structure throughout the body of the drill collar—*for highest tensile and impact strength!*

To get more footage drilled with less drill collar trouble—specify American Iron Premium Steel Drill Collars!

AVAILABLE THROUGH YOUR LOCAL SUPPLY STORE

REGULAR

AMERICAN IRON & MACHINE WORKS CO., INC. — MANUFACTURERS OF OILFIELD EQUIPMENT — A — OKLAHOMA CITY

ROL-FLEX

Another AMF Product
PETROLEUM EQUIPMENT

AMERICAN IRON & MACHINE WORKS COMPANY, INC.
518 North Indiana Avenue • Oklahoma City, Oklahoma
Subsidiary of AMERICAN MACHINE & FOUNDRY COMPANY

For more data on advertised products, use Readers' Service Cards, last page.

THE BEST WAY TO LOWER

OPERATING COSTS....

LOWER

A REDA PUMP INTO YOUR WELL

With investment and labor costs continuing to increase, economy of operation is of paramount importance in producing wells with decreasing oil-water ratios.

Reda-Submergible Pumps are an economical means of producing wells with high fluid volume. Over 80 million barrels of oil have been produced to date from wells previously unprofitable to operate. Not only has production increased, but pumping with Reda extended the ultimate economic life of thousands of wells previously produced at low rates of fluid withdrawal.

Sizes are available to 300 h.p.; capacities from 20 bbls. to 25,000 bbls. per day; depths from 200-feet to over 10,000-feet. Easier, less expensive installation, low operating costs, increased production, greater operating life, and efficient performance lower costs when pumping with Reda.

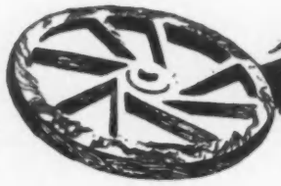
Write today for further information. Reda engineers will be pleased to furnish complete information.

SIGN OF QUALITY . . . SUBMERGIBLE REDA PUMPS

REDA

PUMP COMPANY

BARTLESVILLE, OKLAHOMA



SQUEAKS from the BULLWHEEL

"I wouldn't worry about it—man, our gopher holes go down that deep."

He Tried

A man walked into a bar one night followed by his little dog. The bartender hurried to explain that dogs were not allowed in the place, but the man stopped him with "This is the smartest dog in the world. Doggie, what do we have over us that keeps the rain from coming in?"

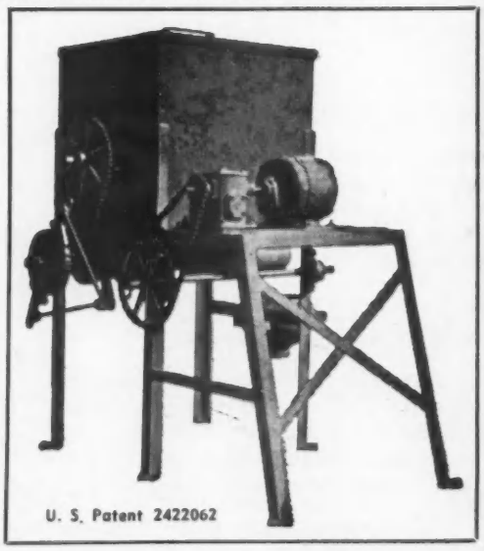
"Roof! Roof!" barked the dog.

THE WESTERN CHEMICAL FEEDER

the dependable, economical water treater

CHECK THESE FEATURES:

- **Used in Oil Well Water Flooding, Municipal Water Treating Plants, Canneries, etc.**
- **Can be driven by water entering plant for treatment.**
- **Maintains pre-set water-chemical ratio through a wide rate-of-flow range.**
- **Adjustable two ways, to feed from a few pounds to several hundred pounds of chemicals per day.**
- **Also can be equipped with electric motor or gas engine drive.**
- **Made to your specifications in various sizes.**
- **In use the world over.**



U. S. Patent 2422062

Whatever your water treating problems may be, investigate the Western Feeder. Write for literature and prices.

For complete description see Page 2843 of the Composite Catalog.

Manufactured By

KEYSTONE SUPPLY CO.

312 E. Cherokee St. Phone LD-10
NOWATA, OKLA.

Over
70
Locations in the United States and Canada

McCullough® REPORTS TO THE OIL INDUSTRY

Service
Anywhere Anytime

New Services • • • New Tools • • • New Methods • • • Outstanding Results

Powerful M-3's Perforate Deep Well for 1296 B/D

McCullough M-3 Bullet Guns Get Production After Jets of Another Make Fail

This deep well in New Mexico had previously been jet perforated by another service company without results.

Producing formation was a 26′ zone between 11,977′ and 12,003′. 5½″ OD 20 lb. casing had been cemented through the zone.

McCullough was called to reperforate the well with M-3 Bullet Perforators. 156 improved ½″ Ogival Bullets, six per foot, were fired in the 26′ interval.

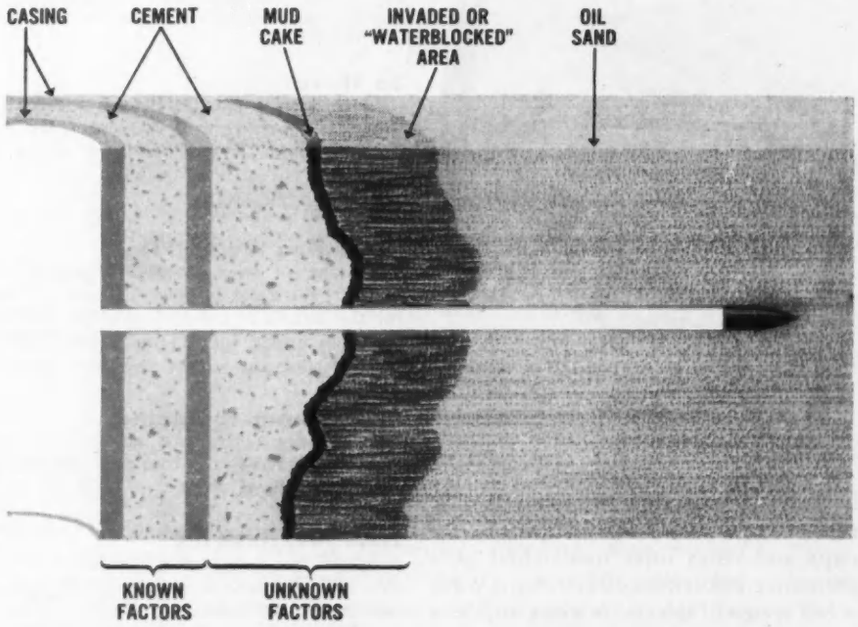
Resulting production was 1296 barrels of oil per day. Operator was very pleased with the good results of the job.

McCullough M-3 Bullet Guns are made to shoot harder—to obtain deepest penetration under severe well conditions. M-3 Guns will get production or increase production even after others have failed.

The job shown above is certified to be a true field report of service rendered.

For full information on the McCullough M-3 Bullet Perforator, write to:

McCullough Tool Company
5820 South Alameda
Los Angeles 58, Calif.



HARDEST SHOOTING M-3 BULLET GUNS
"PUT THE SHOTS WHERE THEY COUNT"—DEEP IN THE OIL ZONE

M-3 Guns are designed to obtain the deepest possible penetration. They have the extra firing power necessary to pierce the known thickness of multiple casing strings with cement in the annulus—to penetrate through an unknown thickness of cement outside the casing—to get through the variable depth of a mud cake and "water blocked" area—to penetrate deep out into the virgin oil zone.

Because they shoot harder, McCullough M-3 Guns get the results you want—better production—more oil! Size for size, M-3's consistently outshoot all other makes of bullet guns.

McCullough® TOOL COMPANY

Cable Address: MACTOOL

LOS ANGELES
HOUSTON
EDMONTON

For more data on advertised products, use Readers' Service Cards, last page.

GET THIS DARCOVA BULLETIN

... featuring cup selector charts!

The advanced design and construction features of Darcova valve cups, seating cups and rings offer unmatched performance, efficiency and economy! With a full range of precision sizes and texture-engineered compositions to choose from you can *meet* conditions exactly! You can prolong pumping efficiency and cut replacement costs!

Take advantage. Send for Bulletin 5502 . . . and specify DARCOVA

DARLING VALVE & MANUFACTURING COMPANY

DARCOVA ®

THE ORIGINAL COMPOSITION CUP

WILLIAMSPORT 28, PA.

"Would you be interested in leasing your island for oil well test while awaiting rescue?"

"Get him out of here!" snorted the bartender.

"Just a minute," protested the man. "Doggie, who's the greatest baseball player the world has ever seen?"

"Ruth! Ruth!" barked the dog.

"That does it!" snapped the bartender, as he ordered the man and dog out the door with a push which landed them on the street. As the man brushed off his clothes, the dog sidled up to him and said "DiMaggio?"

So There!

Dorm Counsellor: "I have a report here that says you have soda, Coke and whiskey in your room. What do you make of that?"

Frosh: "Highballs."

A-Hunting We Will Go

In one of the elementary grades, the teacher, during a science discussion, asked for the names of the four seasons, and one little boy piped up: "Duck season, rabbit season, pheasant season and deer season."

One Woman to Another

"Why don't you just go to him in a perfectly straight-forward way and lie about the whole thing?"

Hear Me, Hear Me

Speaker: "I have lived in this town all my life. By actual count, there are 35 saloons in the town, and I am proud to say I have never been in one of them."

Voice: "Which one is that?"

How True

Because a girl is lovesick is no sign she'll take any old pill that comes along.

Tired Thru and Thru

Husband: "What did the man say was wrong with the tire?"

Wife: "He said the air was beginning to show through."

We Didn't Know

Teacher: "How many sexes are there?"

Little Boy: "Three."

Teacher: "What are they?"

Little Boy: "The male sex, the female sex and insects."

Need More Evidence?

Two women chattered pleasantly as they started off shopping one day. "That neighbor of yours," said one, "she's a bit of a gossip, isn't she?"

"I don't like to say," replied the other, "but when she came home from her summer's vacation, her tongue was sunburned."

For Transmigration?

One tomcat met another tomcat.

"Meow," said the first.

"Moo," replied the second.

"Have you gone crazy?" said the first tomcat.

"No," came the proud reply. "I've been studying foreign languages!"

For Better Grades

A coed with brains goes to the head of the professor's class, but a coed with class goes to the head of the professor.

Language Barrier

Boss: "What in the world happened to you? You're over an hour late getting back with those mules."

Hired Hand: "I know it, Boss, but I picked up Father O'Leary on my way home and from there on the mules couldn't understand a word I said.

In One Easy Lesson?

A recent newspaper ad of a University School of Accounting was headed: "Short Course In Accounting for Women."

Not long after the ad appeared, a note reached the school's president. It said: "There is NO accounting for women."

Plenty of Hot Air

"It was so cold where we were," related one engineer, just back from a job in the Arctic, "that the candle flame froze and we couldn't blow it out."

"That's nothing," jibed a rival engineer, "where we were the words came out of our mouths in pieces of ice, and we had to fry them to see what we had said."

Winner to the End

A golfing clergyman had been beaten badly by a parishioner, 30 years his senior. He returned to the clubhouse rather disgruntled.

"Cheer up," his opponent said. "Remember, you win at the finish. You'll probably be burying me someday."

"Yes, but even then," said the preacher, "it will be your hole."

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Since 1922

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Water Flooding **Gas Repressuring**

EVALUATION CORE ANALYSIS
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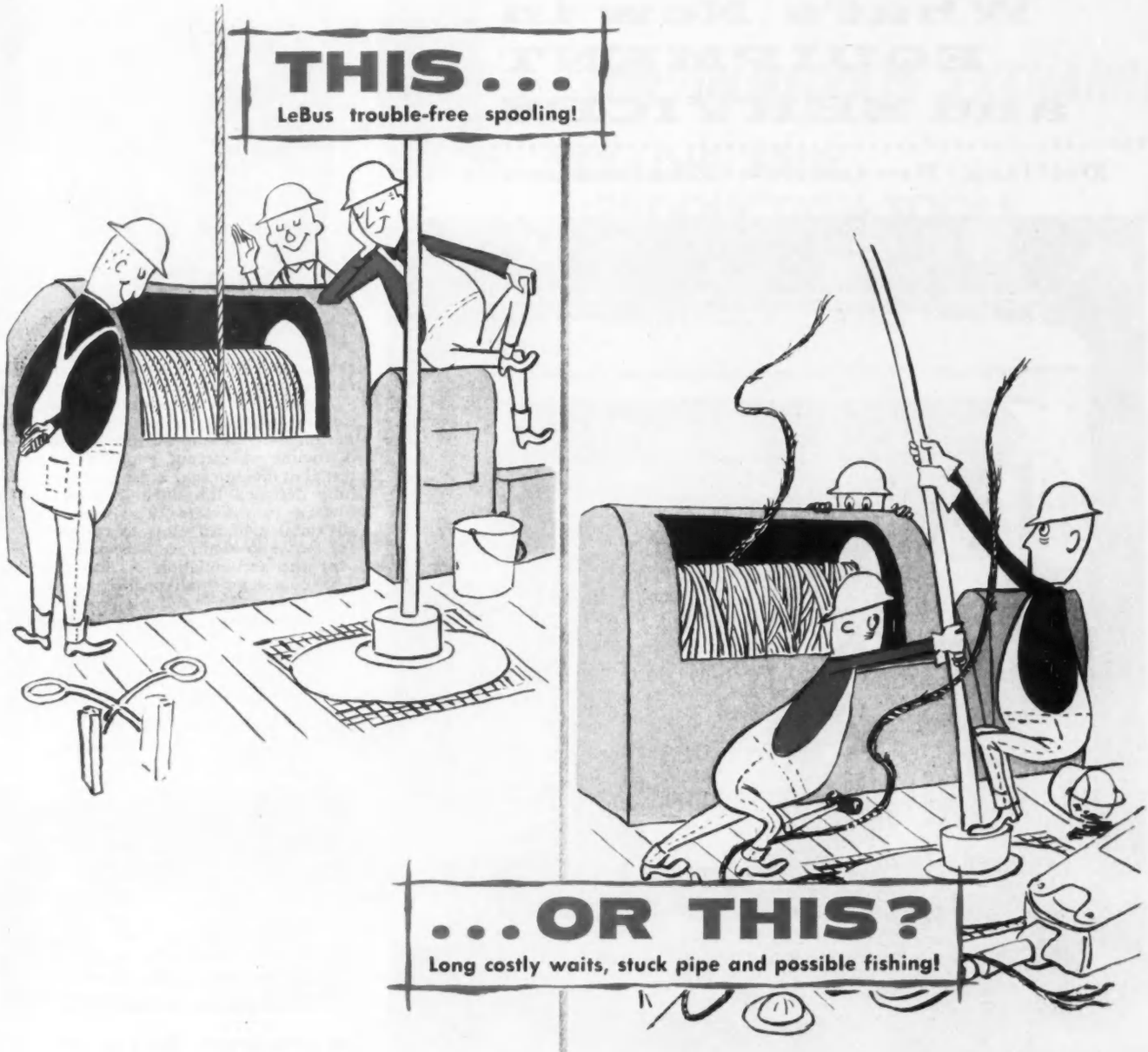
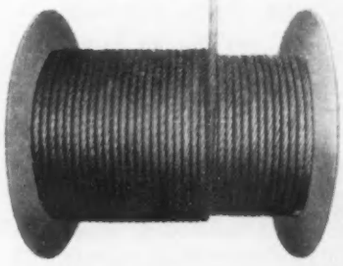


You can get rid of all the troubles caused by wire line breaks when you install LeBus Engineered Spooling. That's because LeBus has engineered *trouble-free* spooling. For example, with *the* new LeBus Counterbalance Spooling System you get perfect spooling every time no matter how many layers of rope you have on your drum.

The result is much less line wear . . . less vibration . . . faster hoisting . . . and an end to frequent line breaks or other costly delays caused by improper spooling. For *perfect* Engineered Spooling . . . whether you need LeBus Counterbalance, Pyramid or Helical Spooling Systems . . . call or wire LeBus World Headquarters for Engineered Spooling, at Longview, Texas.

WRITE today for the new LEBUS WIRE LINE SPOOLING HANDBOOK (4th edition) just off the press



LEBUS

INTERNATIONAL ENGINEERS, INC.

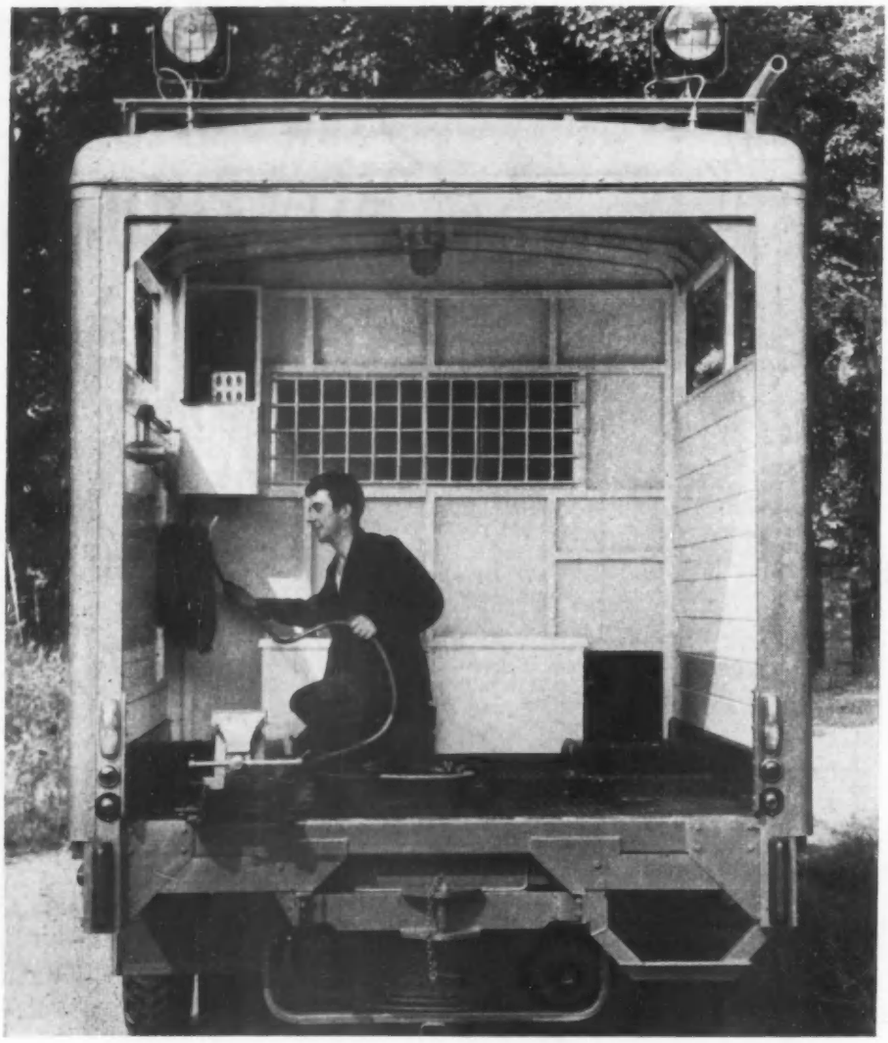
LONGVIEW, TEXAS

For low cost, trouble-free spooling . . . be sure it's LeBus Engineered.

LEBUS . . . WORLD HEADQUARTERS FOR *Engineered Spooling* COUNTERBALANCE - PYRAMID - HELICAL

What's New in EQUIPMENT and SERVICES

Drilling - Production - Exploration



Repair Trucks

First of their kind to be made in the United Kingdom, two trucks, each a mobile workshop, with radio cabin and aerial, were shipped recently to Compania Shell de Venezuela for use by oil field workers.

Each truck is divided into two compartments. The forward one, 4 feet 8 inches long, 6 feet 6 inches wide, is fitted with a sliding door and is provided with foam rubber seating and handrail for the use of the crew and a steel table and loose chair for the radio operator. A light alloy aerial mast is fixed to the outside corner of the truck.

Facilities for the carriage of long lengths of pipe are provided by a ducting at floor level extending through the partition to an access flap in the front bulkhead. A 6-inch engineers vice on a sliding draw-out support allows the manipulation of long pipes across the rear of the body.

The trucks were made by Messrs. O. B. Lywood Limited, Hayes, Middlesex.

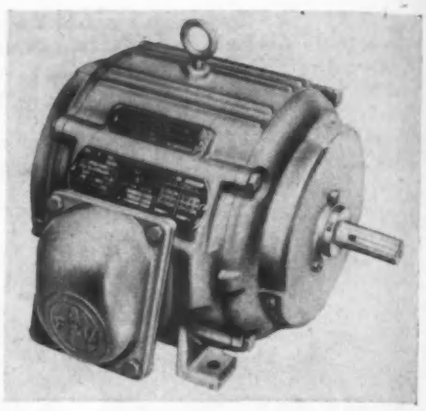
For more data, circle **No. E1** on Readers' Service Card, last page this issue.

Explosion-Proof Motors

Hazardous locations plus electric motors can equal accidental explosions, but not with a new line of totally-enclosed, explosion-proof motors just announced by Fairbanks, Morse & Co. Designed to eliminate fires or explosions when motors must be operated in combustible or explosive atmospheres, these motors incorporate several new features.

Offered in both fan-cooled and non-ventilated models, these F-M motors are all manufactured in strict accordance with latest NEMA standards.

Fairbanks-Morse Type KZCK explosion-proof fan-cooled motors, manufactured in

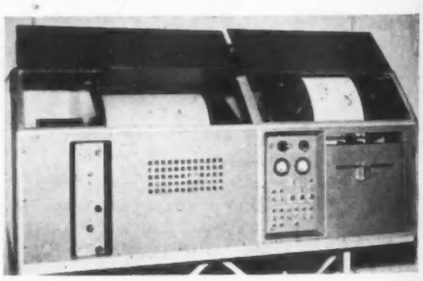


ratings of 1½ to 30 horsepower, incorporate a unique and efficient cooling system.

Trapped clean air within the motor enclosure is transferred by rotor action to the large frame and bearing arm surfaces. A cooling air stream, supplied by an external aluminum fan, is directed by a carefully designed fan shield over the motor surface to dissipate this heat. The air stream is confined close to the surface of the motor to eliminate hot spots, and prevent the accumulation of dust and dirt. The numerous small openings on air intakes provide for an ample flow of cooling air, but prevent large foreign objects from being drawn in by the fan.

(This item supplements Fairbanks, Morse & Co. data on Pages 1737-1756 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E2** on Readers' Service Card, last page this issue.



Seismogram Converter

The Seisverter was introduced by Seismograph Service Corporation recently. This device for converting conventional seismograms into the more modern magnetic recordings, compensated for timing, static and dynamic corrections, incorporates ease in handling, reflection data improvement and facility for data display into a single unit.

Though use of the Seisverter, old recordings may be integrated with those taken with magnetic systems.

Among the possible uses of the device in seismic prospecting is the processing of conventional seismograms so as to place them in magnetic storage for replay and presentation as variable density cross-sections for comparison with the original hand-computed cross-sections.

For more data, circle **No. E3** on Readers' Service Card, last page this issue.

Long-Wear Tapes

Two new long-wearing magnetic tapes for instrumentation use that outwear conventional "Scotch" brand instrumentation tapes by an average of six to 1—yet increase short wave length response by

IN STOCK . . . FOR *IMMEDIATE EXCHANGE*

- **DRILLING AND PRODUCTION TOOLS**
- **PIPELINE AND REFINERY VALVES**

New Facilities For Larger Inventories To Provide Faster, More Efficient Service

Greatly expanded facilities have resulted from the recent merger of Houston Slush Pump Repair Co., Inc., and Snelling Manufacturing Co. In this new plant, with 52,000 square feet of space, complete inventories of exchange fluid ends, power cases, valves and other drilling, production and refinery equipment are available for immediate delivery on a 24-hour a day basis—in order to provide the finest service possible to our valued customers throughout the nation.

With the most complete stock of drilling and production tools and pipeline and refinery valves, Houston Slush Pump Repair Company is providing rapid, 'round the clock exchange replacement service.

Users of this efficient, streamlined exchange service benefit in many ways:

1. Shutdown or waiting time is eliminated.
2. The customer's need for surplus inventories is eliminated.
3. The exchange material is guaranteed to give "same-as-new" service.
4. Exchange is made at the same price as for "renewing."

So, whether the need is for slush pump fluid ends, power or steam ends, slush pump liners, rotary roller drive bushings or housings, rotary tongs, slips or slip inserts, plug or gate valves, swivel wash pipes or other related equipment, call Houston Slush Pump Repair Company—serving the industry for 23 years with specialized service.

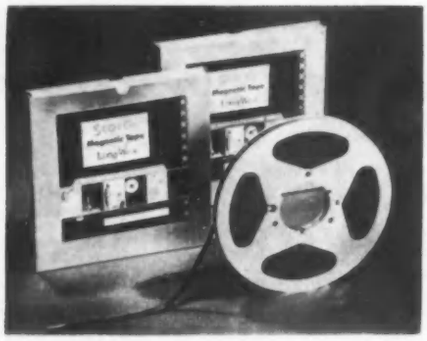
Slush Pump Specialists

HOUSTON
SLUSH PUMP REPAIR COMPANY, INC.

Specializing in rebuilding and machining sand-washed liner cylinders, valve seat ports and rebuilding power ends.

P. O. BOX 2112 **HOUSTON, TEXAS** **PHONE CA 3-4301**

For more data on advertised products, use Readers' Service Cards, last page.



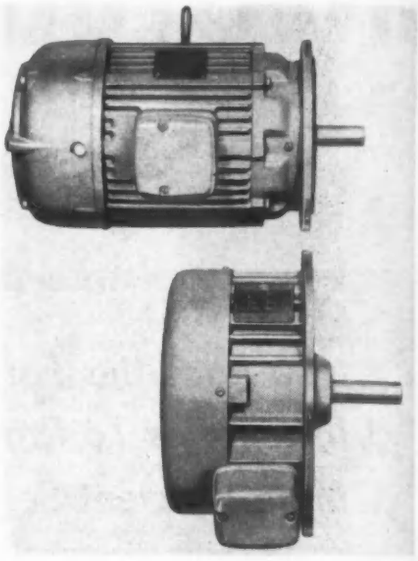
3.5 db—have been introduced by Minnesota Mining and Manufacturing Co.

The new "Long Wear" magnetic tapes, latest addition to the "Scotch" brand instrumentation tape line, are designated No. 148 and No. 149.

Such applications include airborne and telemetering recording, computers, tape control systems for machine tools and geophysical recording.

Key to the superior wear characteristics of the new tape is a new, more durable binder construction which minimizes problems of oxide rub-off and deposit on the machine heads. Under development for more than three years, the new binder is similar to that used in the firm's "Scotch" brand video recording tape. The new tapes include a smoother oxide surface resulting in decreased head wear and employ a durable polyester backing for maximum dimensional stability over a wide range of temperatures and humidity.

For more data, circle **No. E4** on Readers' Service Card, last page this issue.



Pancake Motor

The Louis Allen Co. recently announced a new pancake motor that reduces motor length up to 60 percent over standard motors of the same rating. It is designed for use on machine tools, roof-ventilating fans and many other space-cramped applications.

The pancake motor is a flange-type motor of conventional radial air-gap design. It achieves its short length, without any reduction in motor performance, through formed end coils and a one-piece housing-bearing bracket.

For normal operating conditions it is built in an open drip-proof enclosure. Where dirt, filings, corrosive chemicals, coolants or other contaminants are present, it is furnished in an enclosed construction.

For more data, circle **No. E5** on Readers' Service Card, last page this issue.

Remote Control Unit

A remote control console, designed with application flexibility for obsolescence-free operation, is available from Motorola, Inc. The compact console extends the control function of any remotely-located two-way radio base station to the dispatcher's office over two or four wire lines.

Attractively styled to meet new functional decorating trends, the all-metal housing has provisions for 13 controls on the front panel. These 13 positions may be utilized for one or more of the "kits"

Big Ben

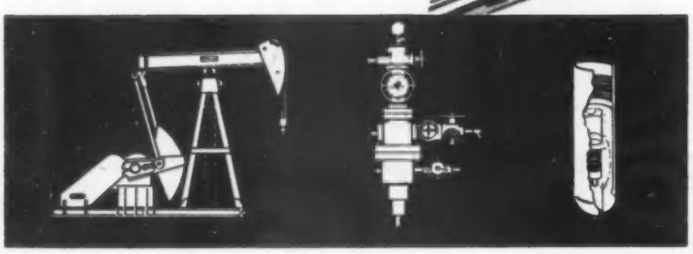
This Most Famous Clock

is named after Sir Benjamin Hall who was London's Commissioner of Works when Big Ben was installed exactly 100 years ago. The mechanism which has kept Big Ben reliable and accurate during the past century is a tribute to British industrial craftsmanship.

This renowned clock symbolises to the people of the world qualities of endurance and reliability, the same qualities which have gained for LeGrand its outstanding reputation in Oilfields the world over.

At their plant in Rochester, Kent, all the knowledge and experience of years of Oilfield technique go into producing a wide range of equipment, including the famous "L" series Pumping Unit; LeGrand OCT. Wellhead equipment; LeGrand-Howco floating equipment; and LeGrand-S. C. Carter long-stroke Hydraulic Pumping Units; Davey Compressor light Rotary Air Drilling Rigs

LEGRAND



For full details, please write to:

LE GRAND ROCHESTER LIMITED

HORSTED AIRPORT • ROCHESTER, KENT, ENGLAND

Telephone: CHATHAM 44626

Also represented in the following countries:

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South West
Calgary, Alberta

TRINIDAD
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14, High Street
San Fernando,
Trinidad, B.W.I.

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E. Venezuela.

Western
A-Z Export S.A.
Apartado 304,
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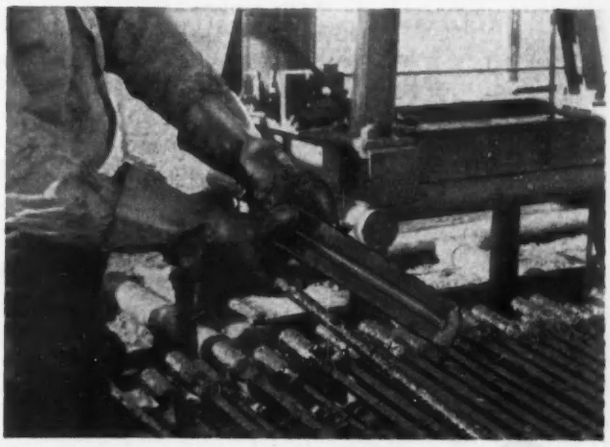
SOLVO®

NEW PARAFFIN REMOVER CONTAINS NO ORGANIC CHLORIDES!

why chlorine-free SOLVO is important to producer and refiner

The organic chlorides found in most chemical paraffin removers remain in the crude—following it to the refinery where they adversely affect the performance of the catalysts used in catalytic reforming. Refinery tests show that as little as 5 gallons of paraffin "solvent" of this kind can contaminate as much as 30,000 barrels of crude, and affect the over-all refinery operation. *SOLVO contains no components which will adversely affect refinery operations.*



Paraffin accumulations such as these plug wells and flow lines, and rob operations of top dollar-efficiency. *SOLVO* has been designed to *prevent* such deposition and eliminate the necessity for frequent pulling and steaming jobs!

how SOLVO is used

SOLVO is available in a variety of formulas; most of which are dispersible in both oil and water, and may be used in either type of diluent. Such dispersions may be relatively concentrated or as dilute as 1%. SOLVO has a high flash point and low vapor pressure, making it safe to use.

effective wherever crude petroleum is produced, transported or stored

Whether your paraffin problem is in a pumping well, tank or flowline, SOLVO works quickly, efficiently, inexpensively. Your local Tretolite Service Engineer is ready to show you how to get the most successful results from this and any other Tretolite product.

TRETOLITE COMPANY

DIVISIONS OF PETROLITE CORPORATION

369 Marshall Avenue, Saint Louis 19, Missouri

5515 Telegraph Road, Los Angeles 22, California

Chemicals and Services for the Petroleum Industry

DEMULSIFICATION • DESALTING • CORROSION INHIBITING • PARAFFIN REMOVAL • SCALE PREVENTION

WATER DE-OILING • INJECTIVITY STIMULATION

TPR-58-2

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Write to nearest headquarters for Illustrated Brochure.

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For more data on advertised products, use Readers' Service Cards, last page.

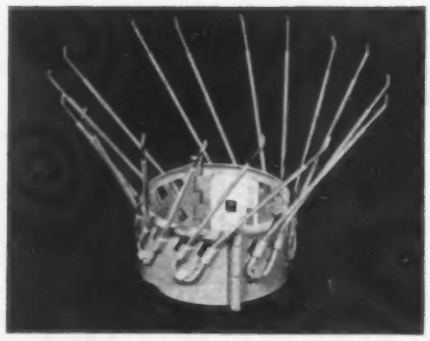
available to meet the needs of the radio dispatcher. As requirements change, new kits may be added to the Console to keep system operation up-to-date.

For more data, circle **No. E6** on Readers' Service Card, last page this issue.

DRILLING

Coil Spring Scratchers

A new line of scratchers is announced by Byron Jackson Tools, Inc., a subsidiary of Borg-Warner Corporation. The BJ red top scratcher features special coil spring steel fingers enclosing wire scratching elements that never kink but always bounce back into position.



Each of the new kind of scratching fingers consists of a sheaf of 10 steel wires held fast in a tightly coiled spring. The protruding wires do the actual scratching, and the coils spring them back to their original position after each stroke and never let them lose their effectiveness. Of equal importance is the fact that the coiled springs prevent damage to the scratching fingers before and during insertion into the hole. A slight dogleg near the tips of the wires keeps them from disturbing the mud cake on the way down.

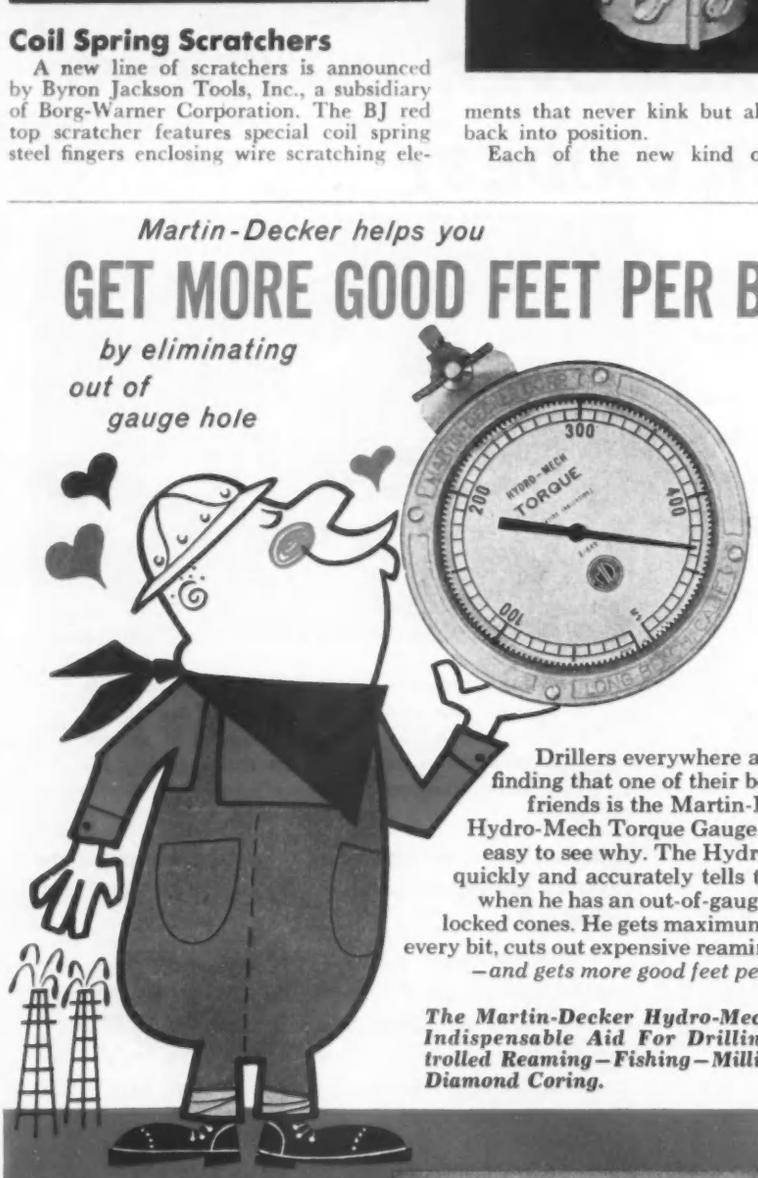
(This item supplements Byron Jackson Tools, Inc., a subsidiary of Borg-Warner Corp., data on Pages 973-1108 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E7** on Readers' Service Card, last page this issue.

Martin-Decker helps you

GET MORE GOOD FEET PER BIT

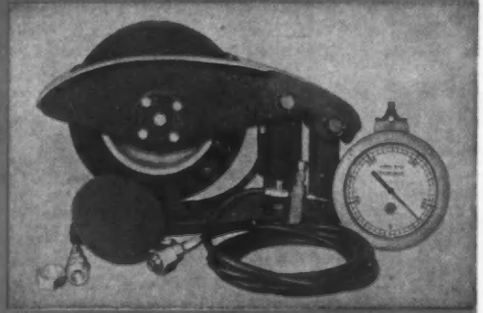
by eliminating out of gauge hole



Drillers everywhere are fast finding that one of their best friends is the Martin-Decker Hydro-Mech Torque Gauge. It's easy to see why. The Hydro-Mech quickly and accurately tells the driller when he has an out-of-gauge hole or locked cones. He gets maximum use from every bit, cuts out expensive reaming time *—and gets more good feet per bit.*

The Martin-Decker Hydro-Mech Is An Indispensable Aid For Drilling—Controlled Reaming—Fishing—Milling—and Diamond Coring.

- A rugged instrument of remarkable sensitivity
- Easy to read and understand
- Operates with any chain driven rotary
- Stabilizes chain and gives it longer life
- Minimizes danger of twist-offs
- Increases footage when drilling with small bits



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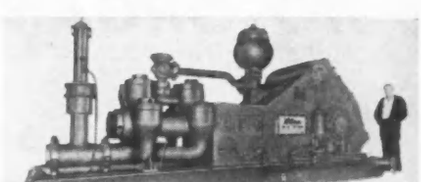


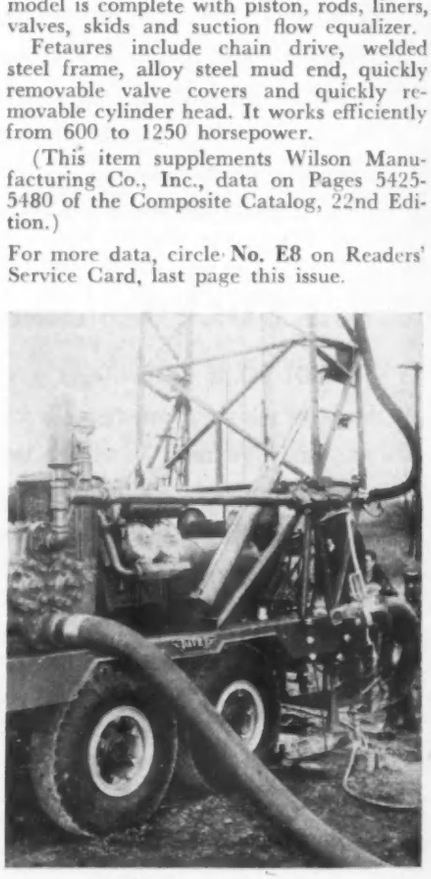
Slush Pump

Wilson Manufacturing Co., Inc., has announced their new 1250-horsepower Titan slush pump. The 35,300-pound model is complete with piston, rods, liners, valves, skids and suction flow equalizer.

Fetaures include chain drive, welded steel frame, alloy steel mud end, quickly removable valve covers and quickly removable cylinder head. It works efficiently from 600 to 1250 horsepower.

(This item supplements Wilson Manufacturing Co., Inc., data on Pages 5425-5480 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E8** on Readers' Service Card, last page this issue.



Rotary Drill

A new truck-mounted rotary drill for air or mud drilling in both rock and sedimentary formations is announced by Davey Compressor Co.

Known as Model M-7WA, it is said to be suitable for gas, oil and water well drilling to depths exceeding 3500 feet with 2⅞-inch pipe and over 2500 feet with 3½-inch pipe. In addition, it can be employed for all types of exploratory and

core work in the mining and construction industries.

An important feature of the M-7WA is its open-faced jack-knife mast. This facilitates use of extra wide break-out tongs and permits setting casings of up to 30 inches without moving the rig. It also results in a 96-inch working area.

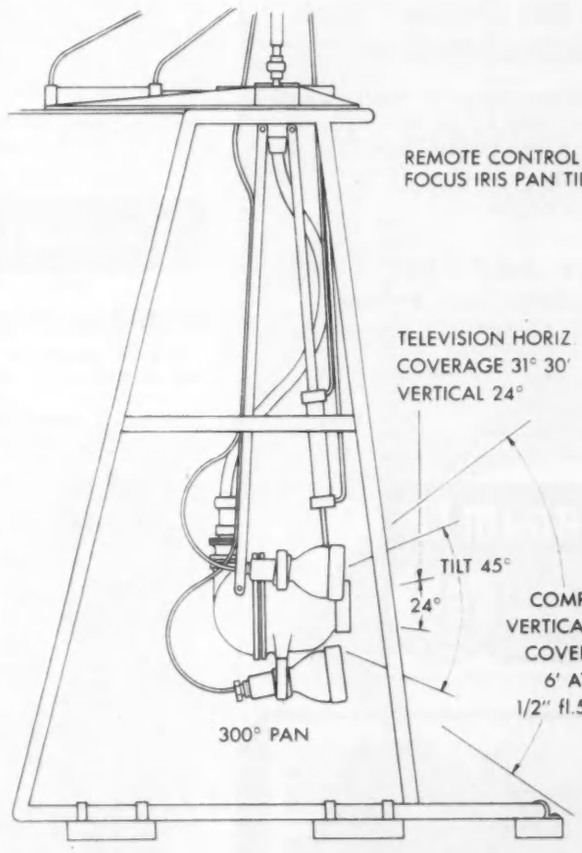
For more data, circle **No. E9** on Readers' Service Card, last page this issue.

Underwater Television

Closed-circuit underwater television units for use in offshore drilling or underwater operations of any type are now available from Medearis Oilwell Supply Corp. The Medearis underwater TV has been successfully operated at 600 feet and is designed to withstand the pressures encountered at depths as great as 1000 feet.

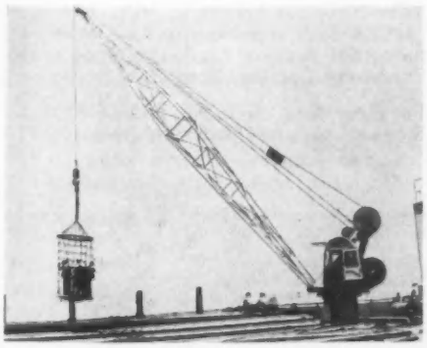
Although each complete assembly is customized to meet individual or special requirements, all electronic components—including remote control, monitor and television camera—are standard, off-the-shelf items requiring no modification.

The remote control and monitoring units are both located above the water, on board a drilling barge or wherever else the operator may desire to place the control point. The TV camera itself is enclosed in a water-tight pressure-tested camera housing measuring approximately 18 inches long by 14 inches in diameter. The housing is cast from corrosion-resistant bronze alloy and contains a 1-inch thick, optically flat ground glass at one end, which acts as a clear window through which the television camera lens can safely resolve submarine views.


REMOTE CONTROL FOR FOCUS IRIS PAN TILT
TELEVISION HORIZ COVERAGE 31° 30'
VERTICAL 24°
TILT 45°
24°
COMPLETE VERTICAL VIEW COVERAGE 6' AT 4' 1/2" fl.5 LENS
300° PAN

(This item supplements Medearis Oil Well Supply Corp. data on Pages 3408-3413 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E10** on Readers' Service Card, last page this issue.



Electric Deck Crane

An all-electric deck crane, featuring positive load control for capacities up to 25 tons, has been placed on the market by R. G. LeTourneau, Inc. They will be available for installation aboard any marine craft, on docks or any other locations where constant lifting is required within a prescribed area.

A principal feature of the crane is powered down-travel. Lowering speed is automatically regulated by regenerative electric braking, which has no wearing parts and never requires adjustments.

Positive stopping control, which permits load positioning to within a fraction of an inch, is assured through a combination of the constantly powered down-travel plus the use of a heavy duty electromechanical brake system.

For more data, circle **No. E11** on Readers' Service Card, last page this issue.

Multiple-Well Derrick

A new multiple-well derrick for offshore drilling has been announced by The Parkersburg Rig and Reel Company. By a

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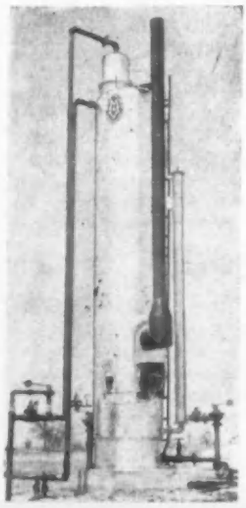

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method of rolling the crown block on wheels operating on trussed headers above the water table beams, three wells can be drilled in a line. The block can then be lifted with the gin pole hoist and positioned for another line of three wells.

Arrangement of cross-over sheave guides the fast line from center line of derrick to correct position above either row of wells.

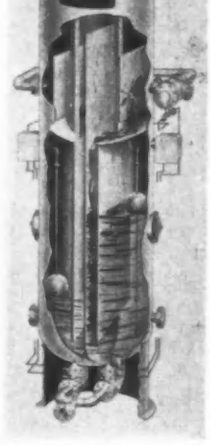
(This item supplements Parkersburg Rig & Reel Company data on Pages 4221-4264 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E12** on Readers' Service Card, last page this issue.

PRODUCTION

High-Flow Separator

A new concept in separating and metering oil well production—a unit which can handle up to 50,000 barrels a day—has been developed by the Rolo Manufacturing Company.

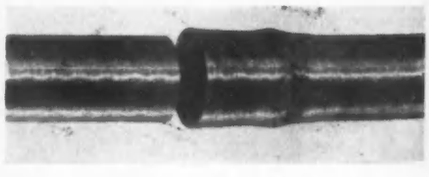


Known as the Hi-Cap metering separator, it incorporates a new design which is an answer to an industry need for an oil metering unit which handles high individual flows, or high combined flow rates. The unit handles low-gravity, viscous crudes easily, as well as high gas entrainment crudes. The problem of high variable gas entrainment is met through metering by weight, as opposed to volumetric metering.

The Rolo Hi-Cap separator has parallel dump-type meter chambers which fill as fast as the incoming flow rate. There is no gravity flow through restrictive lines and valves.

(This item supplements Rolo Manufacturing Co. data on Pages 4564-4565 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E13** on Readers' Service Card, last page this issue.



Epoxy-Glass Pipe

Corrosion-resistant reinforced plastic pipe, strong as steel but only one-eighth the weight, is now being manufactured in 2 to 12-inch diameters to meet ducting, tubing and piping needs of production. The manufacturer, Amercoat Corporation,

uses a patented process employing interwoven fiber glass filaments, impregnated with epoxy resins and heat cured.

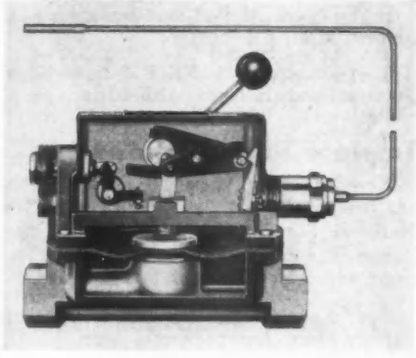
Known as Bondstrand, the new pipe comes in rigid 20-foot lengths with ends plain, bell-and-spigot or flanged. Other lengths, as well as diameters up to 40 inches, are available on special order.

The pipe is nontoxic, nonflammable and crush-resistant, and does not cold flow or sag in use. It may be used for oil water, water disposal, petroleum products, solvents, chemicals and most dilute acids and alkalis. Its smooth, friction-free interior surface resists scale and paraffin deposits, assuring full rate of flow for the life of the pipe.

Two standard series are in production, one with a nominal pressure rating of 250 pounds per square inch (Bondstrand 250) and another rated at 500 psi (Bondstrand 500). Greater pressure ratings may be attained on special order since the manufacturing process permits "beefing up" wall thickness as required.

Tensile strength of Bondstrand pipe is 80,000 psi circumferential and 40,000 longitudinal. Specific gravity of the fiber glass and epoxy material is one-fourth that of steel. Wall thickness, however, is only about half that of steel pipe, so that a finished Bondstrand pipe weighs one-eighth of its steel counterpart.

For more data, circle **No. E14** on Readers' Service Card, last page this issue.



Treater Safeguard

Positive protection for emulsion treaters from pilot failure is achieved with a new safety gas valve recently introduced by The Partlow Corporation. The device, known as Model 760, is operated by a mercury column and requires no electrical connections.

This simple, rugged valve can be opened only after its mercury actuated element has become red hot from contact with the pilot flames. Should the pilot fail or become extinguished, the element cools and releases a latch allowing the valve to snap shut.

A strong perforated diaphragm is used to positively guide the disc to its seat to assure positive closure, even after being in the open position for months.

(This item supplements The Partlow Corp. data on Pages 4266-4267 of the Composite Catalog, 22nd Edition.)

For more data, circle **No. E15** on Readers' Service Card, last page this issue.

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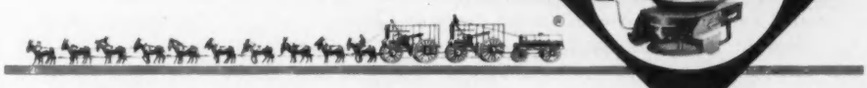

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New Literature

For more data on New Equipment or copies of Catalogs and Literature reviewed in this issue, use the Readers' Service postcards just inside the back cover and facing the Advertisers Index. Simply circle code numbers of items desired—sign and mail card. Requests are transmitted to the manufacturer as soon as received by us for mailing of desired information directly to you.

Breakdown Acid Report

Dowell Incorporated has issued a brochure entitled "Technical Report," which describes and gives uses of breakdown acid. It also shows how breakdown acid works and gives important laboratory data.

To get a copy, circle **No. E16** on Readers' Service Card, last page this issue.

Flexible Coupling Folder

A pamphlet is available from The B.A.L. Group describing the all-metal power transmission flexible coupling. The principles of the Dynalink coupling and a general description is given. The Dynalink Coupling, standardized non-spacer coupling Type U, Dynalink power transmission flexible coupling, Dynalink spacer coupling Type U and the Dynalink non-spacer coupling is included.

To get a copy, circle **No. E17** on Readers' Service Card, last page this issue.

Triplex Pump Folder

New National Type F-30 Triplex pumps are presented in Bulletin No. 473 by The National Supply Company. Design, performance specifications, oil field applications and selection chart are included.

To get a copy, circle **No. E18** on Readers' Service Card, last page this issue.

Shunt Wound Motor Bulletin

GEA-6691, four pages, with diagrams, charts, lists specifications and illustrates the advantages of the GE752H oil well drilling motor. It is issued by General Electric Company.

To get a copy, circle **No. E19** on Readers' Service Card, last page this issue.

Four Logging Books

Perforating Guns Atlas Corporation now offers two free handbooks with which comparison of 13 performance charts on the PH-125 Neutron/Neutron Log may be made with published charts of other type (neutron-gamma) instruments. The log permits the accurate evaluation of formation porosities. The title—"Porosity Evaluation Charts for PH-125 Logs" and "These Charts Speed Porosity Evaluation of Radiation Logs."

Two other technical bulletins are offered. They provide extensive and illustrated test data on the relative economy,

effectiveness and advantages in choosing between bullets and jets for perforating various types of formations under certain conditions. They are "Should We Use Bullets or Jets?" and "Perforating Techniques and Applications."

To get a copy, circle **No. E20** on Readers' Service Card, last page this issue.

Circulation Brochure

A brochure issued by Dowell Incorporated describes Jelflake, a fragmented plastic foil varying from pinhead size up to two-inch pieces, for stopping or preventing lost circulation.

To get a copy, circle **No. E21** on Readers' Service Card, last page this issue.

Rock Bit Information

Globe Oil Tools Co., recently published a new folder illustrating and describing their two and three-cutter Task-Type rock bits. Also included in this new folder are two new Globe three-cutter rock bits, designed especially for the medium and medium hard formations.

To get a copy, circle **No. E22** on Readers' Service Card, last page this issue.

Pump Anchor Brochure

The Fluid Packed Pump Company announces a new four-page illustrated bulletin on the Oilmaster insert pump anchor. Technical Bulletin #T5801 covers installation and operational details of the pump anchor with the unique vertical-setting mechanism.

To get a copy, circle **No. E23** on Readers' Service Card, last page this issue.

Access Fittings Manual

A fully illustrated catalog of access fittings for oil wells (drilling, completion and production) and industries requiring means of entry into equipment under pressure, has just been published by Cosasco division, Perfect Circle Corporation. The 32-page, 8½ by 11 plastic bound catalog shows cutaway views and tabulations of sizes and types of Cosasco access fittings for all applications.

To get a copy, circle **No. E24** on Readers' Service Card, last page this issue.

Tubing Swabs Pamphlet

This eight-page catalog contains information on Bell Models 50, 10 and 20 tubing swabs and standard reversible cups, undersize reversible cups and all rubber multi-rib cups. Accessories include overload relief valves, block-type packing rubbers for split type oil savers, rope sockets and ball bearing swivel sinker bar connections.

A useful table on swabs and cups for sizes of tubing and drill pipe is included.

To get a copy, circle **No. E25** on Readers' Service Card, last page this issue.

UP HE POPS... LIKE MAGIC!

William T. Krall, Manager
Singapore

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Composite Catalog, Page 3419

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• Dot preceding name of advertiser indicates that detailed data on products and services of the firm will be found in current 22nd (1957) edition of The Composite Catalog of Oil Field Equipment.

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